بسم الله الرحمن الرحيم

In the Name of God,
the supremely Merciful, the most Kind.

ECONOMIC ANALYSIS OF IRRIGATION INDUCED LAND DEGRADATION IN A CONJUNCTIVE WATER USE ENVIRONMENT

By

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DECLARATION

I hereby declare that the content of the thesis, entitled **"Economic Analysis of Irrigation Induced Land Degradation in a Conjunctive Water Use Environment" "** are product of my own research and no part has been copied from any published source (except the references, standard mathematical or genetic models/equation/formulae etc.). I further declare that this work has not been submitted for award of any other diploma/degree. The university may take action if the information provided is found inaccurate at any stage.

Muhammad Avais Tahir

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Dedicated

To

My Beloved

Parents

And

Family Members

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All the praises are credited to the sole creator of the entire universe **ALMIGHTY ALLAH**, The Most Beneficent, The Most Merciful and The Most Compassionate, Who granted me the power of vision and wisdom to unknot the mysteries of the universe in a more systematic manner what people call it SCIENCE. And only by the grace of **ALLAH**, I was capable to make this material contribution to already existing ocean of knowledge. I invoke Allah's blessings and peace for my beloved Prophet **HAZRAT MOHAMMAD** (PBUH), who is eternally present torch of direction and knowledge for humanity as a whole and whose honorable and spiritual teachings enlightened my heart, soul and mind.

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ABSTRACT

Being an agrarian economy of Pakistan, increased agricultural productivity is central towards sustainable economic growth, alleviating poverty and ensuring food security in the country. Irrigation plays a significant role in the growth of agriculture particularly crop sector. Irrigation constitutes a mixture of both canal and underground water. The role of groundwater is most important than surface water for irrigation purpose because the dependence on groundwater has been increased which ranged from 65 percent (in the head end) to 90 percent (tail end areas). In Punjab province of Pakistan about 75 percent of the irrigated area is dependent on the pumped/ ground water. The saline groundwater when applied for irrigation purpose causes more salinity in the area which limits the agricultural production and deteriorates the quality of agricultural land. This problem is becoming a serious threat to the sustainability of irrigated agriculture in the country particularly in the Punjab province, wherein about more than 50 percent of the groundwater is saline causing a huge secondary salinization in the irrigated soils. This study will focus on land degradation issues being occurred due to irrigation induced salinity with saline groundwater in a conjunctive water use environment, regarding its consequent effects on crop productivity, resource use and economic valuation of such degraded land. The study was conducted in the selected areas of Punjab province of Pakistan, having irrigation-induced salinity affected soils (with saline ground water) and the area having good soils (fresh groundwater for conjunctive use) for its comparison. Production Function approach and its decomposition analysis and Logit/ Probit model analysis was used to address the above mentioned objectives of the study. Economic loss per acre per annum of sample farmers was Rs.30238. This was significant amount/income per acre which was not being received to the farmers annually. So, this is the value of land degradation which was being paid by the farmers in saline areas. If these economic losses were measured in overall study areas, it became about Rs.31.5 million per year and similarly these losses were Rs. 232591 million which comes to US $ 2326 million per year in Punjab's agrarian (crop production) economy.

CHAPTER 1 INTRODUCTION

1.1 Background

Being an agrarian economy of Pakistan, increased agricultural productivity is central towards sustainable economic growth, alleviating poverty and ensuring food security in the country. No doubt the share of agriculture sector has been steadily declining than of other sectors, still agriculture remains a dominant sector of

Pakistan's economy. Currently, agriculture has about 21 percent sectoral share in total GDP of the country, out of which about 9 percent is contributed by the crop sector (GOP, 2014).

The direct and indirect roles of agriculture are very important in inducing economic growth. A study of Asian countries, where agriculture is the main stay of the economy, found that an increase of 1 percent agricultural growth led to a 1.5 percent increase in growth of non-agricultural sector due to strong backward linkages to industries related to farm inputs, chemicals, fertilizers, machinery as well as food and fibre processing (Rehman *et al.* 2011).

Punjab is the largest province and has major share in agricultural GDP of the country. It has 12.2 million hectares of cultivated area which is about 57 percent of the total cultivated area of the country. As for as irrigated area is concerned about 76 percent of the total country's irrigated area lies in the Punjab Province. Similarly a large share of major crops in lieu of acreage and production comes from this Province. The area under major crops, like wheat is being sown at about 74 percent of the total crop area, and corresponding figures for Rice, Sugarcane and Cotton are 66, 71 and 85 percent, respectively (GOP, 2013). A pictorial view of acreage under these crops with respect to Punjab and Pakistan is shown in Figure 3.1. Keeping this background in view, it is evident that Punjab province has pivotal role in agriculture sector (crop sector) of the country.

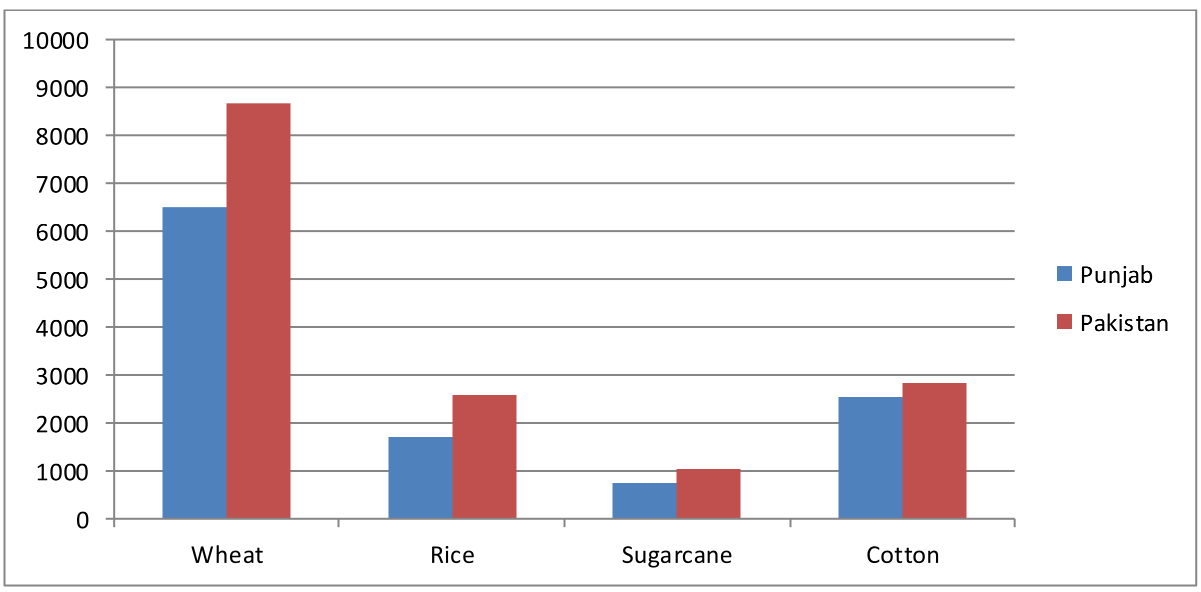


Figure 1.1: Area under major crops in Punjab and Pakistan (000 hectares)
Source: GOP, 2013

1.2 Irrigation: a conjunctive use environment

Irrigation plays a significant role in the growth of agriculture particularly crop sector. By increasing world food and fiber demand, irrigation sector is being expanding immensely to cater these needs. Irrigation is being applied worldwide on about 260 million ha. Pakistan is amongst major four countries i.e China, India, and United States, account for over half of the world's irrigated land. Many countries including Pakistan rely on irrigated land for more than half of their domestic food production. On these irrigated farms, two or three crops per year are grown. Therefore, by high cropping intensity and safeguarding food security the spread of irrigation would be the key to this century's rise in food production (Ahmad, 2002).

Irrigation constitutes a mixture of both canal and underground water. The usage of conjunctive ground water varies depending upon the availability of canal water and location of the farm i.e at head end and tail end reaches of canal. The surface water availability is decreasing globally and during the last 10 to 20 years, there has been a significant increase in the use of groundwater resources for agricultural irrigation (Clarke *et al.* 1996). This has not been restricted to semi-arid regions, but also occurred in more humid areas, in order to provide a greater intensity as well as more reliable supplies for existing cultivated areas. Groundwater has been the heart of the green revolution in agriculture across many Asian nations, and has permitted cultivation of high value crops in various arid to semi-arid regions. Today, the United States, China, India, and Pakistan are the biggest consumers of groundwater and its use is still increasing (Postel ,1999). In India it is 32 percent, Pakistan 30 percent and China 11percent. In some of the most populous and poverty stricken regions of the world, particularly in South Asia, groundwater use has emerged at the centre of the food-agriculture economy (Ahmad, 2002).

Global Water Partnership (2012) reported that last 20-30 years have witnessed a global boom in groundwater use for irrigation. Today's irrigated agriculture was the largest abstractor and consumer of groundwater, with almost 40 percent of all cultivated land under irrigation being "water well equipped" with large groundwater-dependent agro-economies in South & East Asia. The regions with the largest groundwater use are shown in Table 1.1.

Table 1.1: Global survey of groundwater irrigation

Region	Groundwater Irrigation	
	M ha	Proportion of total (%)
Global Total	112.9	38
South Asia	48.3	57
South- East Asia	1.0	5
Middle East & North Africa	12.9	43
Latin America	2.5	18
Sub-Saharan Africa	0.4	6

Source: Global Water Partnership, 2012 and Siebert *et al.*2010

In Pakistan, Indus Basin irrigation system irrigates an area of about 15 million ha, diverting annually about 128 billion m^3 of surface water to 43 canal systems (GOP, 2013 and Badruddin, 1996). During the last 30 years, extensive public development of Pakistan's groundwater resources has taken place through vertical drainage schemes, entailing the installation of about 16,000 public tube wells, serving also to increase irrigation supplies. Increased cropping intensities, government subsidies and the example of the public tube wells, have stimulated farmers to install a large number of private tubewells (Kuper, 1997).

The fact that the Indus Basin is a conjunctive use environment is not a new phenomenon. At the start of the 19th century, an estimated number of 350,000 hand and dug wells existed in the Punjab (including Indian Punjab) and the North-West Frontier Province, contributing supposedly about 40% of the total irrigation supplies (Kuper 1997). The surface water availability in the country has decreased during last 8 years from 101 MAF (Million Acre Feet) in the year 2005-06 to 89 MAF in 2012-13. A decrease from 2.5 percent (2005-06) to 13.4 percent (2012-13) was observed (Figure 1.2).

By increasing demand of irrigation and shortage of surface water supply, groundwater is being supplemented with surface water as a conjunctive use. The number of tubewells installed for groundwater withdrawals for irrigation purpose in the province during last 10 years has been increased from 610,750 (Nos.) in the year 2001-02 to 954,706 (Nos.) during the year 2011-12 (Figure 1.3). It shows that groundwater is not only supplemental to surface water, but has now become an essential part of the irrigated agriculture in the Province.

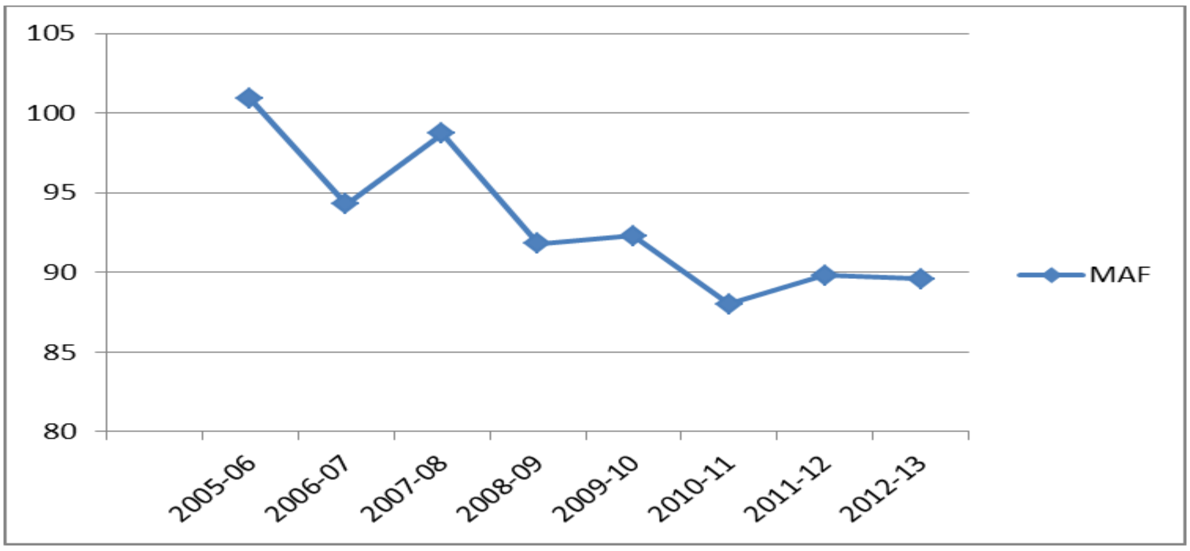


Figure 1.2: Surface Water Availability (MAF)
Source: GOP, 2014

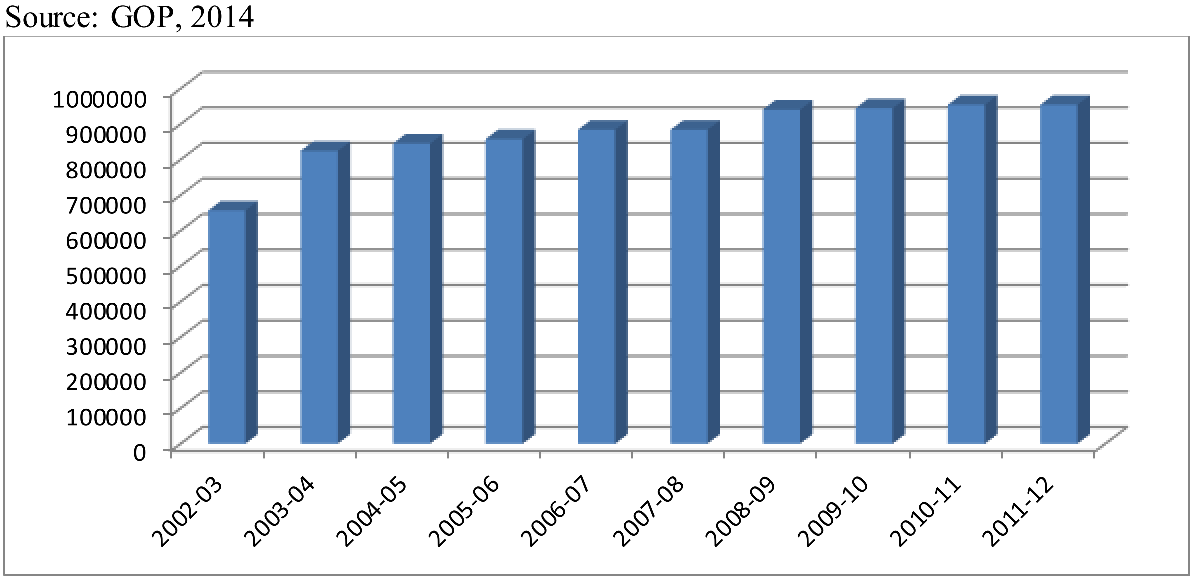


Figure 1.3: Number of tubewells installed in Punjab province
Source: GOP, 2013

Various studies have shown that role of groundwater is important than surface water for irrigation purpose because the dependence on groundwater has been increased which ranged from 65 percent (in the head end areas) to 90 percent at tail end areas (Rust and Velde, 1994). In Punjab province of Pakistan about 75 percent of the irrigated area is dependent on the pumped/ ground water. The total available groundwater resource of the Punjab Province was estimated 42.75 MAF (GOP, 2013). During the last 18 years, the use of tubewell irrigation as well as conjunctive use has been increased (Table 1.2).

Table 1.2: Area Irrigated by different sources in Punjab province

(million ha)

Year	Irrigated Area	Source of irrigation		
		Canal	Tubewells	Conjunctive use
1994-95	13.26	4.18	2.52	6.51

2000-01	14.05	3.82	2.78	7.23
2006-07	14.57	3.58	3.02	7.93
2011-12	14.55	3.28	3.12	8.05

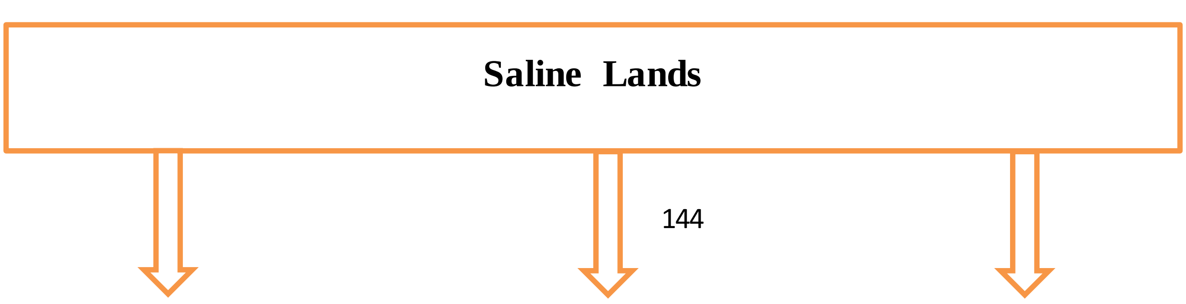
Source: GOP, 2013

1.3 Irrigation Induced Land Degradation

Soil salinity is a worldwide issue and generally its extent is higher in arid and semi-arid environment, where often limited and unreliable surface water supply exists and on the other hand groundwater is also saline. It is a natural phenomenon as well as due to mismanagement of irrigation. Similarly, salinity has also been associated with irrigated agriculture in the Indus Basin (Framji *et al.* 1984, Ahmed and Chaudry, 1988). Generally salinity was considered to be linked with waterlogging and the rise of the groundwater table, which occurred due to the introduction of large-scale perennial irrigation in the Indus Basin. However, as reported by the Soil Survey of Pakistan in 1970s that the causes of salinity were much more diversified. Basically, three main causes were identified i.e Genetic salinity, due to weathering of parent material, rise in groundwater tables and use of poor quality groundwater by tubewells. This poor and unfit groundwater has turned into an important issue due to the massive deployment of tube wells in the Indus Basin and has imminent threat of secondary salinization and degradation of agricultural lands (Kuper, 1997 and Qureshi *et al.* 2003).

On the contrary, in fresh groundwater areas, depletion of the aquifer and a fall of the phreatic surface are caused by unplanned over utilization of groundwater. In many irrigation systems, this leads to deterioration of groundwater quality due to saltwater intrusion from saline zones. Persistent reliance on such groundwater in irrigated areas has resulted in the transport of salts from deep aquifers into the root zone which follows secondary salinity and sodicity. This is also happening in the Indus basin irrigation system of Pakistan where some parts are waterlogged, while others show overdraft (Ahmad, 2002). Before the introduction of the earthen gravity irrigation system, the phreatic surface was 20 to 30 m deep, and a natural water balance was established. But with the construction of large gravity irrigation systems, this balance has been disturbed. This has adversely affected the environment by causing secondary salinization (Wolter and Bhutta, 1997and IGRAC, 2009).

There are three major types of salinity (Figure 1.4) based on soil and groundwater processes found all over the world and these are different from the normal classification of ‘Primary’ or ‘Secondary’ salinity or saline and sodic soils. These are: (i) Groundwater associated salinity (GAS) where water exits from groundwater to the soil surface bringing the salts dissolved in it or through application of saline water; (ii) Non-groundwater-associated salinity (NAS) prevails in those lands where the water table is deep and drainage is poor, salts, which are introduced by rain, weathering, and Aeolian deposits are stored within the soil solum; (iii) Irrigation associated salinity (IAS) occurs where salts introduced by irrigation water are stored within the root zone because of insufficient leaching. Poor quality irrigation water, low hydraulic conductivity of soil layers and high evaporative conditions accelerate this irrigation-induced salinity. Use of highly saline effluent water and improper drainage and soil management increase the risk of salinity in irrigated soils (Ghassemi *et al.* 1995 and Rengasamy, 2006).



Groundwater Associated Salinity(GAS)

Non-Groundwater Associated Salinity (NGAS)

Irrigation Associated Salinity (IAS)

Figure 1.4: Causes of Irrigation induced salinity

Source: Rengasamy, 2006

Sagasta and Burke (2010) also defined causes and types of salinity. There are both natural and human caused that can induce accumulation of salt in soils and water resources. Natural salinity refers to the 'primary' salinity that was present prior to the development of land for agriculture, and human-induced salinity refers to the 'secondary' salinity often caused by land-use change. The main cause for salt mobilization is irrigation and excessive irrigation raised water tables from saline aquifers and this can increase seepage of saline groundwater into water courses and increase their salinization. In almost all countries where land salinization is a major problem, it is accompanied by water salinization. Major problems have been reported in Pakistan, China, United States, India, Argentina, Sudan and many countries in Central and Western Asia (Table 1.3). The use of saline or sodic waters is a common practice in these countries such as not only for salt-tolerant plants and trees, but also conventional grains and forage.

Table 1.3: Countries with area salinized by Irrigation

Country	**Area (Mill ha)**
Pakistan	7.0
China	6.7
United States	4.9
India	3.3
Uzbekistan	2.2
Iran	2.1
Iraq	1.8
Turkey	1.5

Source: (AQUASTAT and Ghassemi *et al.*, 1995 quoted by Sagasta and Burke, 2010).

Secondary salinization has been observed the most harmful and extended fact of the disparaging effects of irrigation on the soil as well as environment (Verma *et al*. 2008).

Soil salinity and alkalinity are mainly caused by natural and cultural (secondary salinization) factors. The climate, natural drainage, geological structure, parent material are natural factors whereas, unsuitable irrigation methods and water quality, inefficient drainage are cultural or secondary factors. The use of saline (unfit) groundwater for irrigation would degrade the soils (Mehanni, 1998, Ozcan and Cetin 1998). This practice may also give rise to some apparent and hidden soil problems directly or indirectly associated with tubewell irrigation (Mohtadulllah, 1997).

Salinity is a water quality problem of increasing importance in many irrigated areas. In arid and semiarid countries this problem is particularly serious because: (a) Brackish water is often the only supply available for regional development. (b) Increasing population pressure causes more marginal lands to be brought under cultivation and increases the need for using brackish water for irrigation (Shiati,1989).

Conjunctive use of canal and groundwater has become the lifeblood of irrigated agriculture throughout the Indus Basin. Typically, head end areas have groundwater with EC values of less than 1 dS/m (having more recharge) rising to over 3 dS/m in tail end areas. When the quality of both surface and groundwater used by farmers was examined, only the top 40 percent of the distributary got water of adequate quality, the next 40 percent obtained below average quality, while the tail 20 percent of farmers irrigate with water that is classified as saline. The result was a clear increase in soil salinity from head to tail along distributary canals, and there was evidence of more land abandonment in tail end watercourses as compared to middle due to excess salinity (Rust and Velde, 1994).

In saline lands i.e both irrigated and non-irrigated, surface water an integral part of normal agriculture is scarce and groundwater available is mostly saline or brackish. This saline groundwater when applied for irrigation purpose causes more salinity in the area which limits the agricultural production and deteriorates the quality of agricultural land. This problem is becoming a serious threat to the sustainability of irrigated agriculture in the country particularly in the Punjab province, wherein about more than 50 percent of the pumped groundwater is saline causing a huge secondary salinization in the irrigated soils (GOP, 2009). Based on the groundwater quality monitoring data, a map/ pictorial view of Punjab regarding groundwater quality with respect to fit and unfit for irrigation purpose is made which is shown in Figure 1.5. Blue colour shows fitness, while red colour is marked for unfit groundwater.

Waterlogging and salinity are twin problems but due to depletion of groundwater table, almost waterlogging problem has been eliminated in the Punjab province. About 32 percent of cultivated area in the province has saline and sodic soils (Table 1.4).

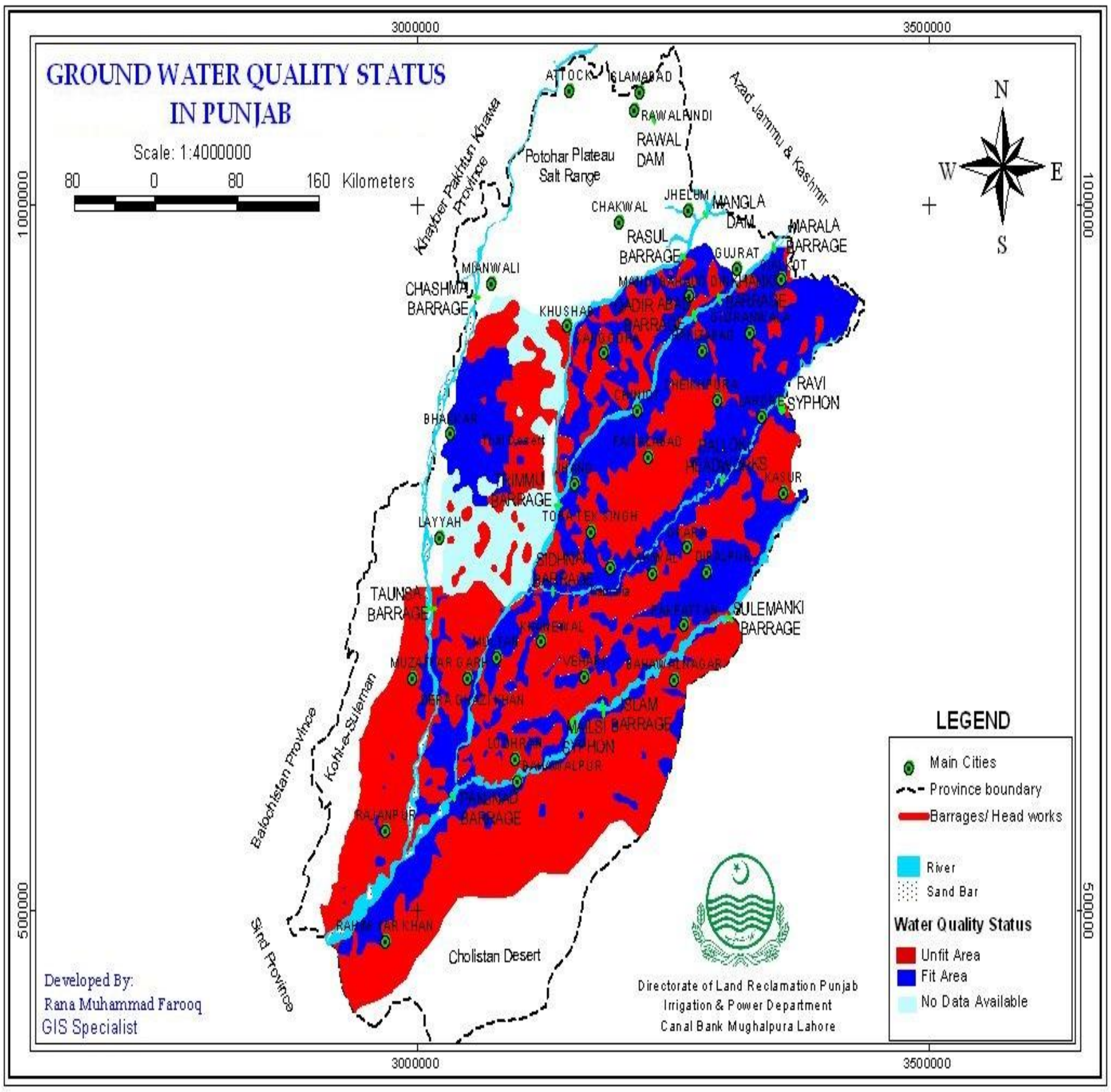


Figure 1.5: Groundwater Quality in Punjab
Source : GOP, 2012

Table 1.4: Extent of Salinity & Sodic Soils

Province	Saline & Sodic soils (%)
Punjab	32
Sindh	61
KPK	16
Baluchistan	54
Pakistan (overall)	43

Source: GOP, 2013

1.4 Consequences of Irrigation Induced Salinization/ Land Degradation

The rapid development of tubewells in the country and Punjab province is a clear indication of the current level of farmer's reliance on groundwater for irrigation. Groundwater can be a primary buffer against drought, since groundwater systems tend to respond more slowly than surface water systems to short-term variability in climate. However, the mismanagement of this buffering system and more use of saline groundwater has direct and serious impacts on the environment and ultimately agricultural land degradation.

Salinization is major hindrance regarding the sustainable use of irrigated agricultural lands and ensuring livelihoods of the farming communities, particularly the small land holders in those distressed areas. Food and Agriculture Organization (FAO, 2005) in its report stated that high contents of salts significantly reduced the value and yield of soils causing socio-economic, environmental and food security problems in the long run. By recognizing the symptoms of salt-affected soils in time may save costly reclamation efforts and further land losses.

Soil salinity and non- agricultural use of agricultural lands are major causes of squeezing the precious agricultural lands and have posed a serious threat to the agricultural economy and food security of the country. International Water Management Institute (IWMI, 1998) reported that soil resources degradation caused by land abandonment and loss in crop productivity through salinity has demanded urgent and efficient efforts in the affected areas so that ever higher demands for food, supply of raw material for agro based industry and foreign exchange from the agricultural sector may be ensured.

Salinity induced productivity losses could become more significant in the context of yield growth in future scenario as yield growth rates were forecasted to fall more than 1 percent per year over the future few decades. The impact of land degradation on productivity could affect the situation of food security in such areas both through reduction in cumulative production, so higher prices of food for consumers and through reduction in income for those persons whose livelihood was derived from agricultural land or labour associated with agricultural activities (Wiebe, 2003).

Salinization of land has threatened civilizations in ancient and modern times. Soil salinization in southern Mesopotamia and in several parts of the Tigris–Euphrates valley destroyed the ancient societies that had successfully thrived for several centuries. In modern times, salt-affected soils are naturally present in more than 100 countries of the world where many regions are also affected by irrigation-induced salinization (Rengasamy, 2006).

The increase in agricultural land degradation reduced the cumulative Gross Domestic Product (GDP). These cumulative losses between the year 2006 and 2015 were calculated more than 4 billion US$, which were equivalent to almost 5 percent of the total GDP in 10 years period in Ghana. Whereas, the consequences of agricultural degradation on poverty was also significant at the national level , which were equivalent to rise in 5 percentage points by the year 2015 as compared to the case with no land degradation (IFPRI, 2007).

According to the World Bank, total annual cost of crop losses due to salinity in Pakistan were estimated from Rs. 15 to 55 billion. On an average, economic loss was Rs. 35 billion per annum, which is equal to almost 0.6 percent of the GDP in 2004. It was further highlighted that 25 percent reduction in crop production of Pakistan is mainly attributed to salinity (WB 2006). The loss of livelihood is a major threat to the security of the country as the major issue related to Pakistan's economy is the unemployment and lack of adequate employability in the rural areas.

1.5 Need for the Study

Land base for agriculture has been decreasing due to urbanization, industrialization and population explosion. Irrigation induced soil degradation particularly due to use of saline groundwater in conjunctive environment has severely damaging the land productivity and posing threats to sustainability of irrigated agriculture and livelihood of the farmers in the irrigated command area. In spite of increasing area under degraded soils, there is not much attention paid to assess the extent of damage caused by these problems and the imminent socio-economic consequences on the farmers. There was need to develop methodologies to compute value of such negative externalities on crop production and social aspects of livelihood. Thus, overall focus of this research is to assess effects of land degradation on farm productivity and returns, to estimate the economic value of such degradation and to identify various factors affecting the adoption of irrigation induced salinity control measures by farmers.

Thus, the study of this type would be highly useful to generate valuable scientific information to understand the degree of influence of this issue on crop productivity and returns. An economic analysis of losses arising out of soil degradation would go a long way in estimating and understanding the extent of losses at the farm level and at the regional level. An effort made in this direction would help planners, policy makers and the researchers to evolve appropriate policies and design remedial measures to bridge the gap and arrest further spread of problems in the irrigated command areas.

In view of all the background information, this study has focused on land degradation issues being occurred due to irrigation induced salinity with saline groundwater in a conjunctive water use environment. The study was conducted in the Punjab province of Pakistan, wherein about 75 percent of the irrigated area is dependent on the pumped/ ground water. The saline groundwater when applied for irrigation purpose causes more salinity in the area which limits the agricultural production and deteriorates the quality of agricultural land. This problem is becoming a serious threat to the sustainability of irrigated agriculture in Punjab province, wherein about more than 50 percent of the groundwater is saline causing a huge secondary salinization in the irrigated soils.

1.6 Objectives of the study

The specific objectives of the study are:

i. To assess the effects of irrigation induced soil salinity on crop productivity, resource use and profitability in conjunctive water use environment.
ii. To identify the socio-economic and physical factors affecting the adoption of irrigation induced salinity control measures by farmers.
iii. To compute the economic value of land degradation.
iv. To suggest policy guidelines for maximizing the economic returns under such irrigation induced land degradation.

1.7 Summary

This chapter briefs about importance of agriculture (crop sector) which remained a dominant sector of economy of Pakistan. The direct and indirect roles of agriculture are very important in inducing economic growth, alleviating poverty and ensuring food security in the country. It also highlights that irrigation plays a vital role in the growth of agriculture particularly crop sector. Irrigation constitutes a mixture of both canal and underground water. The surface water availability in the country has been decreased during last decade. Thus, role of groundwater had become most important than surface water for irrigation purpose because the dependence on groundwater has been increased. The number of tubewells installed for agricultural purpose in the province has been doubled during last two decades which shows that groundwater is not only supplemental to surface water, but has now become an essential part of the irrigated agriculture in the Punjab, province.

The soil salinity is a worldwide issue and generally its extent is more high in arid and semi-arid environment where often surface water is limited and its supply is unreliable and whereas groundwater is also saline. This problem is becoming a serious threat to the sustainability of irrigated agriculture in the country particularly in the Punjab province, wherein about more than 50 percent of the pumped groundwater is saline causing a huge secondary salinization in the irrigated soils. Thus, study in hand had focussed land degradation issues being occurred due to irrigation induced salinity with saline groundwater in a conjunctive water use environment.

1.8 Outline of the thesis

The entire thesis is comprised of five chapters. The first chapter contains a brief rationale of the problem highlighting the significance and scope and objectives of the study. Under second chapter a comprehensive review of available literature keeping in view objectives of the study in view are presented. The third chapter elaborates briefly about the salient features of the study area, sampling frame, methods used for data collection, data sources and analytical approaches/ techniques used. Chapter four covers results and discussions on various socio-economic and farm characteristics, agricultural productivity, returns and resource use pattern of major crops. Results of econometric analysis included Cobb-Douglas Production Function, Production Function Decomposition analysis and Logit Model analysis are also given in this chapter. Summary of the study, its conclusions, limitations of the study and future policy implications are reflected in last chapter.

CHAPTER 2 REVIEW OF LITERATURE

2.1 Background

This chapter entails a comprehensive review of available literature keeping in view objectives of the study. These concerned reviews/ studies were related to local (within the country), regional and worldwide situations. The emphasis of these studies were highlighting the issue of irrigation induced salinity (secondary salinization) and land degradation in conjunctive water environment, its causes particularly the role of saline groundwater (as a conjunctive use) in land degradation, its consequences on crop productivity and losses in monetary terms of such degradation. Major thrust and findings of these studies are elaborated below.

Watson (1978) studied twin-menace of waterlogging and salinity cause reduction in agricultural production by affecting the plant growth adversely. The study highlighted the impact of waterlogging on the production of plants and crops. Wheat, barley and oats were used to document the effects of waterlogging on productivity. In the first experiment, irregular waterlogging reduced the vegetative growth and yield of wheat by 37 %, while continuous waterlogging reduced the vegetative growth and yield by 55 %. Wheat grain yield was reduced by 40% in the case of irregular waterlogging, while reduction was 53 % in the case of continuous waterlogging. The reduction in the grain yield of barley and oats was 39 % for barley and 48 % for oats. In the second experiment waterlogging at the early growth stages resulted in largest reduction in root and grain yield. Grain size was reduced in some of the treatments.

Joshi (1987) studied the worse effects of irrigation induced salinity and water logging on productivity of various crops. Canal irrigation, when used in excessive amount having poor drainage and inadequate quality of groundwater were causing secondary salinity. He reported that soil salinity and waterlogging has direct effects on decrease in agricultural production because of augmentation of salt accumulation and rise of groundwater table. Under these situations, resource use had put negative affiliation with magnitude of soil salinization and which had followed reduction in crop output. It revealed that crop productivity lessened with rise in salinity as proved by the production function analysis. The production of rice decreased to the extent of 84 percent on highly salt affected lands, 50 percent on medium salinity affected soils and 8 percent on less affected soils. Under wheat crop, farmers got minimum production on moderately and severely salt affected soils, as compared to normal soils. Similarly it was happened in case of tobacco crop which was obtained only on normal soils. The author ascribed that reduction in productivity and possessing the land unused were major risks of affected areas. He suggested some measures which could overcome salinity hazards. It included lining of canals, effective drainage practices, best water management applications and use of good quality groundwater.

Mustafa (1991) in his study highlighted that canal water shortage has enhanced the use of groundwater significantly to cater crop water needs. He pointed out that scarcity of fresh water, soil sodicity and salinity were the main hazards in agriculture especially crop sector regarding the sustainable growth in the Indus Basin of Pakistan. In view of lesser availability of fresh water with respect to canal as well as underground water, saline groundwater remained a probable source for fulfilling rising irrigation needs as having high cropping intensities in these areas. This shortage had forced farmers to use more available saline groundwater which occurred broadly in semi-arid and arid environments. Undifferentiating and regular exploitation of inadequate quality of groundwater had instigated a rise in salinity, toxicity and sodicity. He further elaborated that besides decrease in output; the use of such poor / saline groundwater has worsened not only the product quality but also restricted the crop choice to be cultivated. The author urged that coordinated measures adopted at different research stations situated in various agro-climatic regions had generated valuable comprehensions, workable technologies including methods and techniques for better agricultural growth and suitable irrigation methods with poor quality of water. These research efforts established the options of using such poor quality water through selection of salt tolerant crops, crop varieties and cropping pattern. Suitable irrigation management through water application schedules and application methods can maintain less level of salts in the active root zone.

Singh and Nandal (1993) in their study apprehended that soil salinity and waterlogging, a major cause of land degradation, was considering shocking extents in the irrigated territories of Haryana state in India. Authors elaborated that investigations were constructed on the primary data collected from a sample of 248 farmers pertaining to agricultural year 1989- 1990. The study observed the adverse effects of degraded lands on crop productivity. The findings of the study had shown that productivity and returns over variable cost from all major crops had reduced under both types of degraded lands/ soils i.e due to salinity and waterlogging as compared with normal soil comparatively due to degradation effects and partly due to the reduced input levels. It was presented that total estimated loss in the study area due to land degradation was about Rs. 2570 million on account of land unfit and not being used for cultivation and lesser yields in the study area.

Siddiq (1994) studied the causes of waterlogging and salinization in the Indus Basin of Pakistan (IBIS). The canal commands of the Indus Basin were facing problems related to productivity and sustainability of irrigated agriculture. The major constraints were waterlogging and salinity, depletion of soil fertility due to higher cropping intensity and usage of inadequate quality groundwater. Salinity and waterlogging were the most serious problems faced by irrigated agriculture in the basin. The scarcity of canal water provisions enforced the farmers for using groundwater of marginal to brackish in quality resulting in secondary salinization (due to soluble salts) and sodification (due to sodium salts). This inappropriate and inefficient irrigation had raised the water table in the basin. Twin menace of salinity and waterlogging was reducing the productivity of agricultural lands .Under arid climates where saline soils were abundant, high evaporation from the soil surface continuously brought up more water from root zone and through capillary rise, resulted in salt accumulation on the surface. Salinity resulted in slowing down the plant growth and resultantly reduced crop production in the area.

Rust and Velde (1994) in their study entitled "Conjunctive use of canal and groundwater in Punjab, Pakistan: management and policy options" observed that farmers at head end of canals got more canal water as compared to those located at tail ends. Differing to conventional insight, and in some cases farmers at head end used more groundwater than those farmers of tail ends. The study has shown that groundwater has played a more important role in irrigation than surface water, on overall basis ranged from 65 percent dependence on pumped water at head end areas to over 90 percent at tail end areas. The crop choices of farmers seemed to having the amount of good quality canal water they were being received. Growers of head end areas were able to sow more high value basmati rice in the summer and more vegetables in the winter, leaving tail enders to rely on less valuable crops such as fodder and wheat. It highlighted that farmers of tail end areas were not only deprived of their fair share of surface water, but also they had to pump more groundwater proportionately which had shown decreasing quality towards the tail. It found that typically, head end areas have groundwater with EC values of less than 1(dS/m), rising to over 3 (dS/m) in tail end areas. When the quality of both surface and groundwater used by farmers was examined, only top 40 percent of the distributary had availed good quality of water, while the next 40 percent at the middle availed below average quality, whereas at the tail end 20 percent of farmers irrigated their lands with water that was classified as saline. The results were obvious a clear increase in soil salinity from head to tail along distributary canals, and there was evidence of land abandonment in tail end watercourses due to excess salinity caused by poor quality of water.

Mustafa and Pingali (1995) in their research article entitled "intensification induced degradation of irrigated Infrastructure: case of waterlogging and salinity in Pakistan" mentioned that in country like Pakistan, having limited endowments and high population growth pressure, agricultural land degradation was of particular concern. Canal water withdrawal, use of inadequate quality groundwater and high use of chemical fertilizers tended to induce land degradation due to the rise in waterlogging and salinity. They stated that in developing countries like, Pakistan, where agriculture was the major sector of the economy, about half of the labour force was engaged in agriculture and more than 70 percent population lived in rural areas, so the menace of agricultural land degradation due to salinity was of great concern. This land degradation not only affected efficient utilization of scarce resources but also reduced the farmer's as well as national income. This study also indicated that land degradation particularly secondary salinity has occurred due to defective and mismanaged irrigation system. Shortage of surface water and increased use of saline groundwater had exerted secondary salinization. Special attention may be given to efficient use of canal water. There was a need to increase public irrigation investment for its improvement and efficient utilization. Tubewell installation should be restricted to the good quality groundwater area. If the groundwater was saline then its utilization would be a high risk because saline water was major cause of secondary salinity and land degradation. Authors urged that there was dire need to assess the irrigation system performance and the optimum ratios of poor/ saline and good/non saline irrigation water for beneficial crop production. Proper amelioration of these soils could be affected instantly and economically by using gypsum.

Gajja *et al*. (1996) examined the impact of irrigation induced land degradation on output and returns for selected crops of sugarcane and rice under different soil salinity environments in Indian Gujrat. They reported that crop productivity reduced with the rise in the level of soil salinity/ degradation regarding various irrigability classes i.e access to good to poor quality of irrigation. It was found that highest yield was noted in normal soils (class I) and under land irrigability class II, whereas, lowest productivity was observed on severely degraded land to an extent of 72 percent for both the crops. The moderately degraded soils recorded 45 percent less crop yields as compared with normal soils. A substantial difference in net income was also perceived between normal and degraded agricultural lands. It concluded that sowing of crops was not established to be an attractive proposition on severely degraded lands having irrigability classes III and IV. It needed focused and special attention to overcome or minimize such irrigation related land degradation issues.

Rosegrant and Ringler (1997) reported that soil degradation was severe problem in many parts of the world and has posed risk to ensure food security. According to them, various sorts of land degradation occurred all over the world. It included irrigation and chemical degradation which were much more important and accounted for 40 percent of the estimated 562 million hectares of degraded agricultural land. Such degradation had reduced total factor productivity, which required more use of inputs levels to sustain yields. The estimated cumulative crop productivity loss due to soil degradation for the period 1945 to 1990 was about five percent of the GDP (gross domestic product) value.

Gowrishankar and Dhinakaran (1997) examined the various factors which were cause of responsible for land degradation. These factors largely involved socio-economic, climate change, soil related and irrigation management practices. Authors concluded that reduction in agricultural productivity was the major apparent economic impact of land degradation. Other instant consequences of land degradation involved reduction in crop outputs, lessening profits, fall in the worth of land and damage of water resources. Living standards in rural areas, which were relying on agricultural income worsened more with the decrease in the per capita availability of productive agricultural land. The study recommended certain remedial measures for combating degradation issues, such as chemical amelioration, agro-forestry and irrigation management practices.

Parshad and Singh (1997) in their study briefed that salt affected soils had placed an important environmental and ecological problems in India and it was estimated that 8.4 million hectare of agricultural land in 1992 was affected by this menace. In addition to agricultural threats i.e dropping fertile agricultural land and employment opportunities due to saline and waterlogged situations, there was severe risk of human diseases like, malaria, dysentery and other water borne diseases. As a result of this soil degradation, there had been severe damaging threats at the farm level regarding sustainability of land resources, decrease in crop productivity due to abandoning crop lands, decline in resource use, displacement of labour from agriculture and widening of income disparities. Authors calculated losses in monetary terms and mentioned that loss in Haryana was Rs. 40 crores and projected to be Rs. 100 crores at 1985 prices by the turn of this century. They discussed these farm level worse effects had provided clear signals that important high value crops would be disappeared gradually from the affected areas since it was not economically worthwhile to grow them on degraded soils.

Rao and Singh (1997) deliberated soil salinity as an important environmental restriction for improving productivity of crops in Gujrat, India. Authors highlighted that salt affected lands were quite widespread in many parts of the state and were lying barren or some native coarse grass was being produced. Salinity even at low levels had turned into highly risky in heavy soils due to their inherent physical and chemical parental properties. This problem of soil salinity was quite extensive and most of the prime lands were going out of cultivation. Keeping in view the sensitivity of the issue and sustaining agricultural growth, authors urged that it required addressing these issues seriously.

IWMI (1998) found that problem of waterlogging and salinity was generally interlinked with each other and has caused high adversarial effects on crop productivity at both individual and collective levels. Besides environmental, economic and social effects, waterlogging and salinity had caused land abandonment and reduction in yields of major crops. The use of agricultural inputs in waterlogged and salinity affected areas was not economical. In such affected areas the reduction in the yields of major crops like wheat, cotton and sugarcane was about 89, 38 and 45 percent, respectively under an average input level. In case of progressive farming, the yield loss was even more.

Malik *et al*. (1998) observed that land degradation may cause adverse effects on health and nutritional status of the poor which can fall their productivity. This may be happened both directly as lesser yield of labour (per unit) or land in view of loss of soil quality, and indirectly due to malnutrition and poor health conditions by which physical capacity of labour to work more is reduced. Even in those cases where the poor labourers were healthy, their labour productivity may be lower because of more time being spent for less productive activities like fuel wood collection and also away from agriculture and its related income generation activities due to degradation of agricultural lands.

Alam *et al*. (1999) concluded about 40 percent irrigated lands of Pakistan has fallen under waterlogging and salinity over the years, which shared about 90 percent of the cumulative agricultural produce of the country. This has made the agricultural land non cultivable and pretended a severe threat to the agricultural sector as well as overall economy of the country, because the agriculture was named as the bloodline of country's economy. Waterlogging and salinity were severely affecting agriculture particularly crop sector at scaring rate. They also reported that impact of waterlogging on crop yields was amazing in reduction of yields and production of major crops and similarly the effects of salinity on crop productivity were also severe. This was occurring in mostly valuable fertile agricultural lands of the country and it was evident that if these hazards of waterlogging and salinity were not responded with new methods and tactics on immediate basis, agricultural productivity of the country would be lessened. It was terrible and may result in emptying food basket of the country. They were of the view that repercussions of these hazards may be termed in one word called "disastrous."

Akhter *et al*. (2000) mentioned an absolute solution of the salinity problem which entailed leaching of salts with good quality water and equipped with effective drainage system. Proper disposal sites, suitable drainage paths, sufficient incline for gravity flow and having good quality water were prerequisites for engineering approach to be implemented. However, In Pakistan, engineering approach was difficult to be applied because of inadequate availability of good quality water and absence of drainage system in these affected areas.

Qureshi and Masih (2000) studied the impact of different patterns/ combination of conjunctive use i.e varied ground water quality on soil salinization. Study results revealed that irrigation with fresh groundwater alone had not surety that salinity would not be occurred on sustainable basis because during the whole year below average rainfall could enhance soil salinization in the root zone which reduced crop transpiration. However, optimal mixing/ ratio of fresh groundwater wherein, at least 20 percent canal water would retain the salinity (root zone) below 4 ds/m, the threshold value, whereas a slightly increasing trend was observed. By applying marginal groundwater for irrigation alone, the root zone salinity increased sharply in first 5-6 years and crossed the threshold value. More surface water be mixed to keep the salts well below the depth of root zones. In the third scenario i.e irrigation with saline groundwater, shown major losses likely to be disaster. The only combination which could be sustainable was that of 80 % of canal water mixed with the saline groundwater. Mixing canal water with less than this ratio would not be beneficial and ultimately land would be gone under degradation.

Wichelns (2000) concluded that twin problems of waterlogging and salinity were the major cause of arid regions. This was due to two major necessary resources, the canal water and the assimilative capacity of unconstrained aquifers, which were not being priced or allotted by considering its economic value and opportunity cost. The author hinted that if farm level prices which were paid for irrigation were adjusted with its economic costs and on the other hand defining water supply allocations and keep in mind the drainage capacities, would help in reducing the increasing rate of salinization and waterlogging in many arid areas. The researcher also pointed out that there were not certain economic incentives and subsidized interventions related to irrigation and drainage practices/ measures which may motivate and encourage the farmers to adopt them for long term impacts regarding sustainability of their agricultural lands. A special focus should be given for provision of these incentives and to educate them so that they may adopt such measures easily.

Javaid and Yamin (2001) studied the Punjab, Pakistan irrigation system which had brought a great prosperity to the province but the induction of salinity and water logging on the other hand, due to salt imbalance, higher seepage losses and low canal delivery efficiency (40%) from canal (head) to the field (crop root zone) was becoming a great threat to the agricultural sustainability. Irrigation intensity had increased to 122 percent against the overall designed annual intensity of 63 percent. Statistics shown that intensity of installing more tubewells had been recorded to fill this gap. More than 70 percent of the tubewells installed to make the canal water deficit, pumped groundwater of marginal to unfit quality and add about 129.06 million tons salts. The shallow water table recycling salts had further added 0.14 mt salt load through capillary rise phenomenon. The canal water no doubt was excellent in quality but due to restricted drainage contributes about 20.99 mt every year. The total salt load to the irrigated soils estimated to the tune of 150 mt. The tubewells' alone share was 86 percent. The authors argued that consequential to the conjunctive irrigation use after massive deployment of tubewells, the salt balance was no more maintained and secondary salinity was now becoming a threat and moving towards a dominating position over genetic salinity due to weathering of parent material. They emphasized that there was need to control the menace. Otherwise it would make our soils unproductive within 80 years or so.

Kahlown and Azam (2002) evaluated the individual and combined impacts of waterlogging and salinity on the yields of major crops i.e cotton, wheat, sugarcane and rice. The magnitude of yield losses as a result of the rise in water table, cause of waterlogging and salinity, from 1 to 2 m and less than 1 m was 27 percent for wheat crop and 33 percent for sugarcane crop, while it was 7 percent and 6percent with water table depth of 2 to 3 m. Under cotton it was observed that rise in water table from 2 to 3 m to1to 2 m and less than 1 m contributed a decrease in yield of about 11 percent and 60 percent, correspondingly. The rice crop considering preferred in waterlogging and in contrast to other crops, attributed about 7 percent reduction in yield under lowering of water table from 1 to 2 m to less than 1 m. The wheat and sugarcane crops yielded a decreasing trend with salinity of over 4 dS/m and had complete failure of crops with salinity of greater than 12 dS/m. The cotton crop verified relatively higher salinity tolerance under a deeper water table. Similarly, the rice crop has shown complete failure at salinity level of greater than 12 dS/m under water table depths of less than 1 and 1to 2 m. Thus, it revealed that combined effects of waterlogging and salinity were more injurious to crop yields as compared to the individual effect of waterlogging.

Datta *et al*. (2002) in their study mentioned that twin problems i.e waterlogging and salinity were widespread in the irrigated lands particular in developing countries. At the global level, this problem was limiting agricultural production in some 45 million hectares of irrigated lands. India was bearing no exception to this threat. In findings of their study on adverse effect of waterlogging and soil salinity in north west-region of Haryana briefed that, in the irrigated areas of semi-arid regions, especially in north-west India, a significant recharge to the groundwater had approached to waterlogging and secondary salinization. Unfortunately, information available on the occurrence and spread of waterlogging and salinity in the country were varied and sketchy. The existing approximations ranged from 6 to 13 million hectares of the total irrigated area, where occurrence of this menace was observed.

Samra and Sharma (2002) in their study on safeguarding natural resources and environment described that land degradation was a major hazard to food and environmental security. Degradation under different forms constituted 150 million hectares accounted for 45 percent of the total geographical area. The areas under waterlogging, and salinization & alkalinization together were 9.0 and 9.2 million hectares, correspondingly. The development of the major and medium irrigation related development projects had also instigated degradation of large areas with the occurrence of secondary salinity and waterlogging on an area of 4.5 million hectares. The observation of water table data over a period showed that in almost all the irrigation commands, the water table had arising trend after the introduction of canal irrigation. The annual rise in water table was 0.28 meter in Mahi Right Bank Canal Command (Gujrat), 0.29 to 0.88 meter in Rajasthan Canal Command, 0.30 to 1.0 meter in Western Yamuna and Bhakra Canal Command (Haryana), 0.10-1.0 meter in Sirhind Canal Command (Punjab), 0.68 meter in Sharda Sahayak Canal Command (Uttar Pradesh), 0.60-1.20 meter in Malaprabha Canal Comand (Karnataka), 0.32 meter in Nagarjun Sagar Irrigation Project (Andhra Pradesh) and 0.26 meter in Sriram Sagar Irrigation Project (Andhra Pradesh). Thus having poor drainage, this twin problem was widely spreading in these irrigated areas.

Qureshi *et al*. (2003) conducted a study titled "productivity enhancement in the salt affected lands in Satiana Pilot Project in Punjab, Pakistan. Authors studied the crop productivity situation in detail in salt affected areas which has covered 38 villages. They established that soil salinization and waterlogging had resulted in reduction of yield of various crops. They argued that sometimes this decrease in yield ranged more than 60 percent. Authors also calculated the annual losses in monetary terms due to waterlogging and salinity under Rice-Wheat crop rotation. The loss estimation amounted to the tune of Rs.10 billion (US$ 166 million) per year. The findings of study also disclosed that farmers were more dependent on off-farm activities for sustaining their livelihood in these degraded and salt affected areas.

Jehangir *et al* (2003) has carried out a study regarding mode of irrigation adopted by farmers on farms, their perception about quality of water and productivity difference under conjunctive water use (both saline and fresh groundwater) in the Rechna Doab, Punjab, Pakistan. The results showed that about 93 percent of the farms were using groundwater as a conjunctive use in the Rechna Doab. Among these farmers about 47 percent were using saline and marginal aquifers. These farmers were also facing the major threat of salinity on their farms. The results of the study were glaring evidence of on-farm gains due to the conjunctive use of canal and tubewell water of marginal and of good quality. These gains called for more efficient conjunctive water use on farms. The econometric regression results showed that low and poor quality groundwater hampered wheat productivity on these farms. The economic indicators demonstrated that potential farm income/ benefits could be 30 percent higher under wheat crop if judicious use (optimal ratios) of canal and tubewell irrigation were applied on these farms. Authors insisted that besides applicable government interventions entailed to revert the process of land degradation due to the use of bad quality (saline) groundwater in the brackish areas of Rechna Doab, the government should place a ban on the installation of new tubewells in the areas where threats of up-coning of brackish water was high and should allocate more surface water to these salt affected areas. Farmers of these areas needed to be well educated about the conjunctive use of irrigation water only in fresh groundwater areas so that the effect of secondary salinity could be minimized on their farms.

Wiebe (2003) described how alterations and changes occurred in land/soil quality upset crop productivity and food security situation in the region or country. Salinity induced productivity losses could become more significant in the context of yield growth in future scenario as yield growth rates were forecasted to fall more than 1 percent per year over the future few decades. This land degradation which caused reduction in farm productivity could affect the situation of food security in such areas both through reduction in cumulative production, so higher prices of food for consumers and through reduction in income for those persons whose livelihood was derived from agricultural land or labour associated with agricultural activities. The results of various models suggested that in less income developing countries if crop productivity losses due to land degradation were decreased from 0.2 percent to 0.1 percent per anum on an average, then the number of persons with insufficient nutritional intakes would drop by 5 percentage points over the next spans.

Kumar (2003) observed that groundwater over-exploitation proved as one of the major causes of salinity in Gujarat, India. In most of the arid and semi-arid areas, farmers were exploiting high TDS (Total Dissolved Salts) groundwater for irrigation purpose. This application had approached to the increase in secondary soil salinity producing the hardening of soil surface and lump formation. In order to disrupt these soil lumps to facilitate better growth of crops, farmers had to increase the water application. Thus, over a period of time, more salts get accumulated on the soil surface and the soils started to become saline. Excessive irrigation to leach the salts and specifically the irrigation with saline groundwater approached to irrigation induced soil salinity which had instigated faster loss of organic matter and nutrients. All these resulted ultimately in soil degradation leading to a decline in water productivity as well as land use productivity. As a consequence of this irrigation induced soil salinity had lessened the economic returns from farming. The poor farmers would be the worst affected, as economic constraints would limit their ability to invest more in farming.

Berry *et al.* (2003) observed the lack of a steady approach to value degradation within states of countries and between countries, which had limited the ability to assess the relative severity of the problem at this time. It was recommended that in future valuations of the cost of degradation, the approach might include both direct and indirect costs of degradation at the distressed areas. Poverty was also a contributory cause of degradation when it limited farmer investment in sustaining land productivity, and it turned into after effects of degradation as productivity declined and decreased the income.

Niazi (2003) investigated the root cause of secondary salinization which lead to land degradation in Pakistan. The author revealed that major cause of secondary salinization in Pakistan which ultimately had led towards agricultural land degradation was due to irrigation. Uneven excess of irrigation water, regardless of its quality, to agricultural land had approached to its rigorous and intensive use by both small as well as large land holders. This contributed to lessen its fertility and degradation of lands process at faster rate. The study showed that cash crops were over irrigated by large farmers, whereas small and tenant farmers having small holdings were practicing intensive agriculture to get more benefits from these small holdings. Under intensive use of agriculture (crop sector) where more irrigation was needed and most likely saline groundwater was used in a conjunctive purpose. This intensive farming for small land holders was crucial because they had to strive for self- subsistence, pay for cost of cultivation and land rent on these lands. The use of saline groundwater had caused irrigation induced salinization, waterlogging and abandonment of agricultural lands. This had confined to reduce productivity of all major crops particularly cotton crop which had an important share in crop economy of the country.

Querishi *et al.* (2004) found that declining quality of water and rising needs for food and fibre placed huge pressure for growth of the crop sector and emphasized the use of available water resources more efficiently and tactfully. These stresses were due to mounting pressure for food and inter-sectoral struggle for water, especially for the use of municipal and industrial sectors. The agriculture sector as well as food security of the country in future would be mostly threatened with the low quality of water as compared to recommencing efforts for achieving water conservation goal. Because of inadequacy, fluctuated and unreliable supply of the surface water, the farmers had turned more dependence on the usage of pumped water to fulfil water requirements of crops. Thus, groundwater steadily attained a pivotal role for sustaining agricultural and rural growth of the country. In order to manage available surface and groundwater, intersectoral water management techniques could be beneficial and effective regarding the quantity and quality of water. This would ensure crop production without any harmful effects and threats of soil salinization.

Tyagi (2005) noted that water efficiency in the crop sector mostly used as a standard for determination of water managing and crop production methodologies, were sternly embarrassed by salinity of soil/land and of water. Salinity caused by water was more usual than that of the land and it was mostly the root cause of salinity development in soil largely due to the misuse of saline and brackish groundwater for irrigating crops. The author suggested two major approaches for improving and sustaining crop production in a saline or brackish environment, firstly to modify the environment which suits the plants/crops and secondly adapting plants to suit the prevailing environment. Both these methods were practised either individually or collectively and it was concluded that first technique was used widely because of enabling the plants to react better to water but also to other inputs used for production.

Azhar (2005) evaluated four drainage projects to assess their effects on crop productivity in the Indus Based Irrigation System (IBIS). The study was conducted during 2001-04. The comparison of before and after project conditions showed that grain per plant and tiller per plant had the sharpest reduction from salinity and waterlogging. According to the results, grain yield per plant was decreased by 60 percent, tillers per plant by about 50 percent, and kernel per spike and plant height had a less severe reduction of about 30 percent and 19 percent, correspondingly. Post project results showed that crop yields were considerably enhanced due to project interventions. It revealed the fact that crop yield was reduced due to waterlogging in the absence of drainage system. The yield increase ranged from 13 to 94 percent for most of the crops. Under Rice crop the yield was decreased by 23 percent, exceptionally which was mainly in view of shortage of water supplies. Maximum increase was witnessed in the yield of cotton (80 percent), sugarcane (94 percent) and wheat (67 percent), whereas in chilli crop maximum increase was observed as 147 percent.

World Bank (2006) in its report entitled "Pakistan strategic country environmental assessment" mentioned that waterlogging and salinity was serious issue which affected in reduction of plant growth and resultantly reduced crop production. Pakistan was heavily dependent on agriculture sector and thus loss of agricultural production posed serious threats to the economy by reducing national income. According to the report total annual cost of crop losses due to salinity in Pakistan were estimated from Rs. 15 to 55 billion. On an average, economic loss was Rs. 35 billion per annum, which was equal to almost 0.6% of the GDP in 2004. It was further elaborated that 25% reduction in crop production of Pakistan was mainly attributed to salinity. Thus, loss of livelihood was a major threat to the security of the country as the major issue related to Pakistan's economy was the unemployment and lack of adequate employability particularly in the rural areas.

Hussain *et al*. (2006) studied "causes, origin, genesis and extent of soil salinity" in the sultanate of Oman. A perusal of the study showed that soil salinity was massive problem of the world. Sultanate of Oman being a part of arid agricultural regions was also badly hit by this problem. The major findings of the study indicated that 1.56 m ha were affected from salinity within suitable agricultural land that was calculated as 70 percent of the total culturable land. Authors also calculated crop losses due to this menace. The losses from crops due to salinity were estimated as 49 m US$, while that from deserting of date palm orchards were 4.5 m US$ which accounted for the total losses as 53.5 m US$, per year. The main reasons of salinity were the climatic conditions, salty parent material and spread of secondary salinity due to regular usage of highly saline water. The salinization of irrigated soils by groundwater has become a major process of soil formation in many areas of the Sultanate of Oman.

Rengasamy (2006) endorsed that salinization was defined as the accumulation of water soluble salts in the soil solum or regolith to a level that influence the agricultural production, environmental health and economic welfare. According to the author, salt affected soils occurred in more than one hundred countries of the world with a variety of extent, nature, and properties. No climatic zone in the world was free from salinization, although the general perception was concentrated on arid and semi-arid regions. Soil salinization was a complex process involving the movement of salts and water in soils during seasonal cycles and interactions with groundwater as briefed by the author. Rainfall, aeolian deposits, mineral weathering and stored salts in the soil were the sources of salt accumulation. The surface and groundwater can reallocate these accumulated salts and may also provide additional sources. More attention was given to groundwater associated irrigation salinity, which has affected about 16 percent of the agricultural area in Australia. The author suggested that a special emphasis should be given on those interventions due to which application of poor quality of groundwater may be minimized so that groundwater induced irrigation salinity and implicitly land degradation may be curtailed.

Bhutta and Alam (2006) studied that in view of mounting demand of water for agriculture (crop sector), domestic and industrial use, the exploitation of groundwater has been increasing day by day in Pakistan. Other factors included the increasing population and lack of surface water and inadequate storage, had expanded pressure on increased usage of groundwater. Authors reported that groundwater abstraction had increased annually from 10 billion cubic meter (BCM) in the year 1965 to 68 BCM in the year 2002. Unplanned and unregulated groundwater abstraction in the country had caused serious concerns like, extreme lowering of water table in certain areas, mobilization of deeper saline groundwater, secondary salinization and higher pumping costs. Findings of the study showed that more than 80 percent groundwater exploitation was being done by farmers in private sector and about 70 percent of these tubewells were operating in those areas where groundwater was saline, and being used for irrigation purposes. This was major threat for agricultural lands in those areas where groundwater was saline regarding secondary salinization and land degradation.

IFPRI (2007) in its study which was conducted at Ghana concluded that increase in agricultural land degradation reduced the cumulative GDP. These cumulative losses between the year 2006 and 2015 were predicted as more than 4 billion US$, which were equivalent to almost 5 percent of the total GDP in 10 years period in Ghana. Whereas, the consequences of agricultural degradation on poverty was also significant at the national level, which could equivalent to rise in 5 percentage points by the year 2015 as compared to the case with no land degradation. Effective and viable land and water management for crop production could be helpful to curtail the soil losses and subsequently to overcome the adverse effects and impacts of land degradation regarding crop productivity, income and poverty.

IGRAC (2009) reported that groundwater salinization had caused substantial societal and economic costs on a wider scale. The large scale secondary salinization due to poor quality of groundwater had resulted in reduction of agricultural (crop) sector productivity. This decline in agricultural productivity had led to numerous kinds of much costly interconnected socio-economic harms like, food insecurity, unemployment, migration and loss of livelihood in such irrigation induced (groundwater) salts affected areas. Some studies had also measured the costs of land and water salinization in monetary terms. The Indus Basin Irrigation System (IBIS) of Pakistan immensely enhanced the agricultural production in the country. However, salinization caused by waterlogging and by application of poor quality groundwater had put serious hazards in relation to decline the crop yields at faster rate over the last decades. It concluded that current estimates of losses of land degradation and decreased yields were about US$ 240 per hectare per year in Pakistan.

Zaman and Ahmad (2009) calculated the economic losses in gross value of agricultural production by salinity and waterlogging during the year 2002 amounting to Rs. 133 billion which was almost 3% of GDP in that year and 23% of the agricultural GDP. This was a significant loss to the agricultural GDP and its contribution to the national economy. This loss was not only in the financial terms but at the same time it was loss of assets of the poor farmers. It reduced the livelihood of the resource of poor farmers who were normally small holders. Some of the small holders and resource poor farmers had lost their livelihood due to salinity and waterlogging and they were forced to turn as baggers. The loss of livelihood was a major threat to the security of the country as the major issue related to Pakistan’s economy was the unemployment and lack of adequate employability in the rural areas. The technological and management advancements in the last few decades have demonstrated all over the world that irrigation and irrigated agriculture could be modernized where productivity and sustainability could be enhanced and attained on longer-term basis.

The new resources of water in future would come largely from the saving of existing losses. Therefore improvement in the performance of canal irrigation system would not only provide savings in existing water supplies but at the same time would enhance the productivity leading to savings of Rs. 133 billion per annum. Some of the opportunities were listed as under:

- Integrated land use system covering crops, plants, shrubs and grasses
- Furrow irrigation and planting on beds
- Sprinkler irrigation for managing salinity
- Drip farming as an alternate to use poor quality of water
- Effective drainage system

Richard (2009) explained that the study was charged with measuring the economic impacts of increasing salinity in the Central Valley of USA. The study was conducted assuming that there was no change in policy and, as such, represented the economic impacts associated with taking no action. Additionally, the study was conducted on an aggregate valley-wide basis that required averaging the effects of salinity and, in some cases, costs. Economic and physical effects were quantified using different physical and economic models. The results showed that if salinity continued to increase at the prevalent rate until 2030, the direct annual costs would range from $1 billion to $1.5 billion. Total annual income impacts to California would range between $1.7 billion continued $3 billion by 2030. The income impacts to the Central Valley would range between $1.2 and $2.2 billion. The production of goods and services in California could be reduced from $5 to $8.7 billion a year. The Central Valley output reduction would range between $2.8 to $5.3 billion. Furthermore, there was $145 million per year of non-market costs. In terms of job losses the increase in salinity by 2030 could cost the Central Valley economy 27,000 to 53,000 jobs. California could lose 34,000 to 64,000 jobs.

Nadeem (2010) concluded that subsurface water supply had increased tremendously over time due to its flexibility in meeting the water demand as and when needed. By launching of Salinity Control and Reclamation Projects (SCARPs) in the 1960s, deep and high capacity public tubewells were installed for drainage purpose, which also served the purpose of irrigation especially in fresh groundwater areas. The SCARP tubewells also motivated farming community to install private tubewells to had better control over and flexibility of water supply. There were about one million (10, 00,000) private tube wells were operational to pump groundwater for irrigation of croplands. Consequently, groundwater contributed 40-50 percent of the crop water requirement. Excessive use of groundwater through over-exploitation and the use of saline and poor groundwater for irrigation had posed several challenges to the sustainability of this precious resource as well as agricultural lands. This poor unfit groundwater for crop purpose had created secondary salinization leading to land degradation.

Qadir *et al*. (2010) undertaken a study and found that role of irrigation was central in agricultural development particularly crop production in arid and semi- arid areas. The authors briefed that area of irrigated lands in these regions extended significantly, mainly in the second half of the twentieth century. However, it was hinted that further expansion would be occurred within the limits of annual renewable freshwater resources. Sectoral competition of fresh water amongst agricultural, industrial, domestic and environmental sectors existed already and would certainly be increased with the passage of time. This competition would ultimately lead to a gradual shortage of freshwater allocation to agriculture sector. This phenomenon was expected to continue and more intensified in arid and semi- arid areas, mostly in developing or less developed countries that already were facing threats of high population growth rates and significant extent of land degradation. Under scarcity of fresh water, alternative water resources would be of poor and marginal quality, such as saline water produced by agricultural drainage systems or pumped from saline aquifers. This inadequate quality of water was being used to bridge the gap between crops demand and supply. The use of saline water in agriculture without suitable soil, crop, and irrigation management had placed high risks of land degradation through the development of soil sodicity, salinity, ion-specific toxicity and nutrients imbalance in soils. These hazards had reduced crop productivity and limited crop choice. It was emphasized that usage of poor or saline water for agriculture was likely to increase with increasing water scarcity. Under future thrust, it would be important to modify current irrigation, soil and crop management practices to cope with the inevitable increases in secondary soil salinity and sodicity.

Ondrasek *et al.* (2011) in their study examined different types of land degradation processes being caused by physical, chemical and biological factors. These degradation processes could be in the form of salts accumulation, soil compaction, inorganic or organic contamination, weakened microbial activity, etc. This was due to largely under extreme anthropogenic pressures which had caused severe consequences to natural resources globally in the last century. Amongst them, soil salinization, arising from either natural or human induced causes, had approached to rise in absorption of dissolved salts in the soil profile to a level which hampered crop productivity. Soil salinization had seriously affected environmental health and socio-economic wellbeing of the communities residing in these areas. This menace had several adverse environmental consequences which involved decline in crop yield and quality, disruption of soil aggregates/ structure and land degradation. The areas which had been affected by soil salinity were among the most intensively exploited ones in worldwide agriculture. It revealed that secondary salinization amongst the three soil degradation processes in addition to organic matter decline and contamination has affected almost area of 1 billion hectare globally. Findings of the study showed that secondary salinization was recognized as the major threats to agricultural lands, environmental resources and human health in many developed or developing countries.

Shafiq (2011) in his paper elaborated that out of 80.4 million hectare (mha), total land area of Pakistan, about 32 mha was fit for agriculture as well as forestry purpose. While only 27 mha, was marked as cultivated land, out of which about 16 mha was treated as irrigated area. Under these irrigated lands, both land and groundwater salinization was one of the key desertification progressions in Pakistan. It revealed that about 6.3 mha of land have been affected groundwater salinization. The author also highlighted that apart from a few localized areas, salt affected soils were mainly confined to the Indus plain. It was mentioned that salts had always been part of the Pakistan's agricultural (crop sector) environment. Accumulation of salts at the soil surface remained a key characteristic of arid and semi-arid environments, especially where poor and inadequate irrigation was practiced. Secondary salinity which was mainly resulted due to human activities, existed on the Indus Basin Plains was also due to the expansion of the modern irrigation system in Pakistan. It concluded that excessive seepage during conveyance of canal water to the farm fields and use of saline and unfit groundwater caused the hazard of water logging and salinization which were principal threats to environment and initiating severe injury to national economy in lieu of loss in agricultural productivity.

Global Water Partnership (2012) in its report explained that groundwater irrigation boom was observed at various economic levels in various developing and transforming countries. These economic levels involved from subsistence farming to large scale staple crop production as well as commercial cash crop cultivation. This had brought major socio-economic benefits especially to rural people in many countries. These benefits assisted in alleviating agrarian and rural poverty through increasing food security. It concluded that this all could be done through groundwater abstraction by ensuring water availability at critical times for crop growth and mitigating devastating effects of drought on crop yields. This groundwater boom in South Asia region had also been widely pro-poor, with marginal and small farmers of land holdings less than 2 hectare, which had increased their groundwater-irrigated area by more than three times higher proportionally than farmers with 10 hectare or more land. Besides this economic uplift, it was deeply noticed that in these major areas of irrigated agriculture, irrigation driven salinization hazards had become of serious concerns. The quality of groundwater varied widely with overall hydrogeological setting and climatic regime, and even down the span of major river basins. Soil salinization had risen through a number of distinct and independent mechanisms i.e rising water table due to excessive canal seepage or field application in head end water areas and phreatic salinization and viz a viz naturally saline shallow groundwater was becoming mobilized and more classical coastal lateral intrusion or inland up-coning of saline groundwater due to excessive abstraction of fresh groundwater. An importantly, there were hyper-arid areas in which virtually all groundwater was naturally saline. This implied groundwater salinization and land degradation threats. It suggested that sound diagnosis, close monitoring and careful management was needed so that harmful effects on crop productivity could be minimized.

UNCCD (2013) reported that besides economic aspects of land degradation occurred due to various causes, social aspects were too much important. One of the major aspects could be increase in poverty. This report highlighted that less attention were given to measure the social impacts of land degradation and it was mostly found that their estimation was hindered by lack of social and biophysical data as well as synergies between these impacts and the underlying social causes of land degradation. However, economic modeling has shown how decisions by land users lead to land degradation which could be affected by government policies in unexpected ways. Improving estimates of the magnitudes of economic and social impacts would require better measurements of the extent and rate of change of degradation, and the integration of desertification/ degradation into national statistics and planning methods. While sustainable land management was an important measure for tackling such degradation and desertification issues. Researches on entitlements, environmental justice and vulnerability recommended that handling desertification was not just about adopting physical remedies, as social remedies were equally important. It emphasized that economic and social impacts needed to be managed in an integrated manner, rather than separately, if policies for addressing desertification were to be effective.

2.2 Summary

The main focus of this chapter was to review past studies conducted to measure the impact of irrigation induced salinization/ degradation. These studies were conducted in Pakistan, Punjab province of Pakistan, and different regions and worldwide. The review of literature showed that rationale of most of the studies was directly or indirectly related with the study in hand. Each study had specific features on the basis of objectives and methodology adopted; however, the findings were more or less same.

The research findings revealed that irrigation induced land degradation was very complex process and it was difficult to separate irrigation induced salinity with respect to surface water (over usage and poor drainage) and saline groundwater. However, it was evident that such salinity (due to saline groundwater) has posed major threats for sustainability of irrigated agriculture/ crop production globally as well as in the country. It was obvious that such irrigation induced land degradation has drastic impact on crop productivity which was reduced up to 50 percent, depending upon extent of this salinity and specific crop. A reduction in productivity has squeezed economic returns of farmers. This decline in agricultural productivity has led to numerous kinds of much costly interconnected socio-economic harms like, food insecurity, environmental degradation, unemployment, migration and loss of livelihood in such irrigation induced salts affected areas. In some studies the cost of degradation/ economic losses has also been measured. A number of strategies and program interventions have been suggested to cope with harmful effects of such degradation, in these studies. It was also found that in some areas farmers individually were adopting certain measures to combat secondary salinization and degradation issues.

Literature reveled that in developing countries like Pakistan, where agriculture is the blood line of country's economy, about 40 prcdnt irrigated land has fallen under salinity issues over the years which shared about 90 percent of the accumulative agricultural produce of the country. In Punjab province of Pakistan, having 76 percent of the total irrigated area of the country, more than 50 percent pumped groundwater is saline. In past conjunctive use of water in saline groundwater areas was considered as safe method for agricultural (crops) growth. So, limited economic researches have been conducted on irrigation induced salinity (due to saline groundwater) issues. But, now in view of decreased surface water supply, increased cropping intensity has lead more use of salience/ unfit groundwater, which is accelerating irrigation induced land degradation. Besides, the environmental externalities of soil degradation caused depreciation of soil fertility and productivity. Consequently, the land value and rental value have been falling in such areas. Given this backdrop, the present study is an attempt to estimate the losses/externalities being occurred due to such secondary salinity/ land degradation.

CHAPTER 3 MATERIAL AND METHODS

This chapter elaborates briefly the salient features of the study area, sampling frame, instruments/ methods used for data collection, data sources and analytical approaches/ techniques used in relation to address the objectives of the study. These all are explained as below:

3.1 Study Area and Sampling Frame

The study was conducted in the selected areas of Punjab province of Pakistan, having irrigation-induced salinity affected soils with saline ground water and the areas having good soils with fresh groundwater for conjunctive use, for their comparison. There are mainly five crop production regions exist in the Punjab province. These are :

Punjab -1 : Cotton-Wheat
Punjab -2 : Rice-Wheat
Punjab -3 : Mixed Crops
Punjab -4 : Pulses-Wheat
Punjab -5 : Maize/Wheat-oil seeds

First three crop production regions namely Punjab-1 (Cotton -Wheat), Punjab-2 (Rice –Wheat) and Punjab-3 (Mixed crops) constitute about 80 percent of the cropped area with the conjunctive use of canal and tubewell irrigation (Table 3.1). About 20 percent of the remaining area is under other crop production regions i.e Punjab -4 and Punjab -5 with crops, like maize, pulses, oil seeds, etc., and these two regions do not fall under conjunctive use of irrigation. Thus, as per focus and objective of the study to assess the effects of irrigation induced soil salinity due to saline (unfit) groundwater on crop productivity, resource use, profitability and land degradation in a conjunctive water use environment, three cropping system/ crop production regions i.e Cotton-

Wheat, Rice –Wheat and Mixed crops are relevant because these regions fall under conjunctive use of irrigation of both surface (canal) and groundwater (tubewell).

Table 3.1: Crop Productions Regions in Punjab

Crop Regions	Cropping Pattern	Source of Irrigation	Percentage of cropped area
Punjab -1	Cotton-Wheat	Canal+ Tubewell	35
Punjab -2	Rice-Wheat	Canal+ Tubewell	18
Punjab -3	Mixed Crops	Canal+ Tubewell	26
Punjab -4	Pulses-Wheat	Canal+ Rainfed	12
Punjab -5	Maize/Wheat-oil seeds	Rainfed	8

Source : FAO, 2004.

As mentioned earlier in Chapter 1, more than 50 percent of groundwater extracted under various regions is not fit (saline) for irrigation purpose and under these three crop production regions both saline (unfit) and fresh (fit) ground water was available with varied extents and was being used for irrigation purpose. So, to make the study a representative of these cropping systems, a sample from these three crop production regions/ cropping systems was taken and included in the study.

Punjab has 36 districts which fall under various crop production regions. A map of Pakistan showing various crop production regions in all the five provinces of Pakistan i.e Khyber Pakhtunkhwa, Punjab, Sindh, Baluchistan and Gilgit Bultistan is reflected in Figure 3.1. The districts fall under these three regions are shown in Table 3.2.

Directorate of Land Reclamation, Irrigation and Power Department, Government of Punjab, Pakistan, is carrying out groundwater monitoring survey each year since 2003, throughout Punjab in irrigated zones. Within 1-2 Km of radius, they have established their groundwater monitoring points/ units from which they collect water samples for testing. This exercise is carried out twice a year i.e pre-moonsoon and post-moonsoon rainfalls, to see the impact of recharge on groundwater depth and its quality. This data have been documented in annual reports. A perusal of previous 3-4 years reports have shown no drastic change in groundwater quality.

Table 3.2: Districts under Crop Production Zones

<table>
<tr><th>Crop Production Regions/ Zones</th><th>Districts</th></tr>
<tr><td rowspan="7">Rice – Wheat</td><td>Lahore</td></tr>
<tr><td>Sheikhupura</td></tr>
<tr><td>Nankana Sahib</td></tr>
<tr><td>Mandi Bahudin</td></tr>
<tr><td>Gujranwala</td></tr>
<tr><td>Narowal</td></tr>
<tr><td>Sialkot</td></tr>
<tr><td rowspan="5">Cotton – Wheat</td><td>Sahiwal</td></tr>
<tr><td>Pakpatan</td></tr>
<tr><td>Bahawalnagar</td></tr>
<tr><td>Khanewal</td></tr>
<tr><td>Multan</td></tr>
</table>

	Lodhran
	Bahawalpur
	Rahim Yar Khan
	Vehari
	Dera Ghazi Khan
	Muzaffargarh
	Rajanpur
Mixed	Kasur
	Sargodha
	Faisalabad
	Jhang
	T.T. Singh
	Okara

Source: Ahmad, 2001

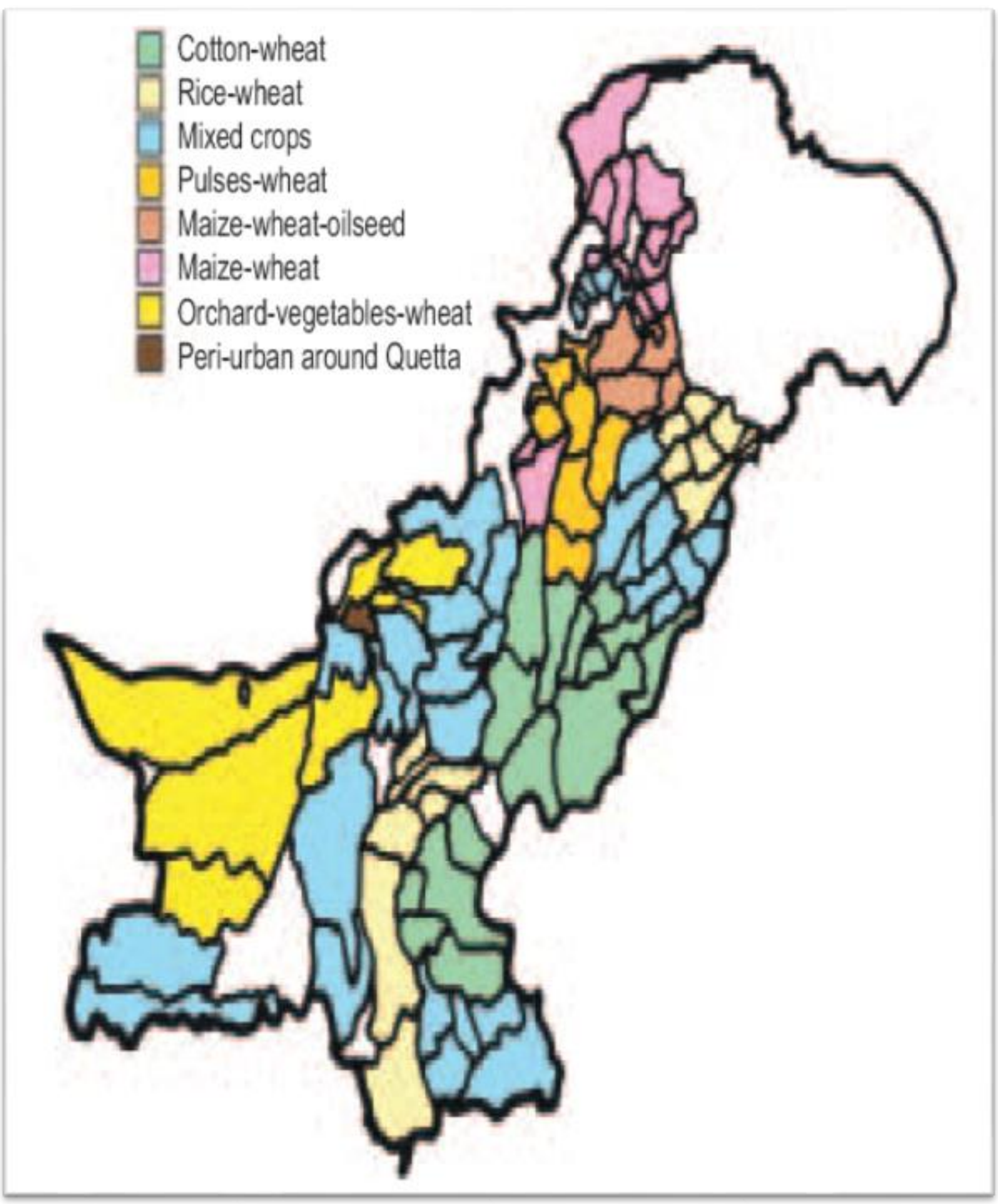


Figure 3.1: Crop Production Regions in Pakistan

Source: FAO, 2004

Groundwater data have been arrayed for the assessment of the temporal variability in both depth to water table and water quality in terms of conventional water quality indicators. It was anticipated that groundwater data being documented will be really useful to the policy makers and irrigation managers while embarking on the agricultural sustainability in the province.

Water samples collected from monitoring points were analyzed for three major conventional water quality parameters i.e. Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC). The major *cations* and *anions* are determined according to the procedures described in USDA Handbook No. 60 in Diagnosis and Improvement of Saline and Alkali Soils. The EC is measured by EC-Meter. The analyzed samples are rated fit or unfit as per irrigation water quality criteria (Table 3.3). The SAR and RSC are computed as per following formula:

$$SAR = Na / \sqrt{Ca+Mg} / 2$$

$$RSC = CO_3 + HCO_3 - Ca - Mg$$ (concentration of ions in me l^{-1})

Table3.3: Irrigation Water Quality Criteria

Indicator	Symbol	Unit	Permissible Level	Unfit Level
Electrical Conductivity	EC	dS/m	≤1.5	>1.5
Sodium Adsorption Ratio	SAR	$(mmol_c / l)1/2$	≤10.0	>10.0
Residual Sodium Carbonate	RSC	me/ l	≤2.5	>2.5

Source : GOP, 2013

Groundwater Monitoring units established by the Department all over the Punjab are shown in Figure 3.2. After consulting this data and obtaining reports of all monitoring points, total three (3) districts i.e one from each cropping region were selected randomly. These districts included Bahawalnagar (Cotton-Wheat), Nankana Sahib (Rice-Wheat) and Faisalabad (Mixed crops).

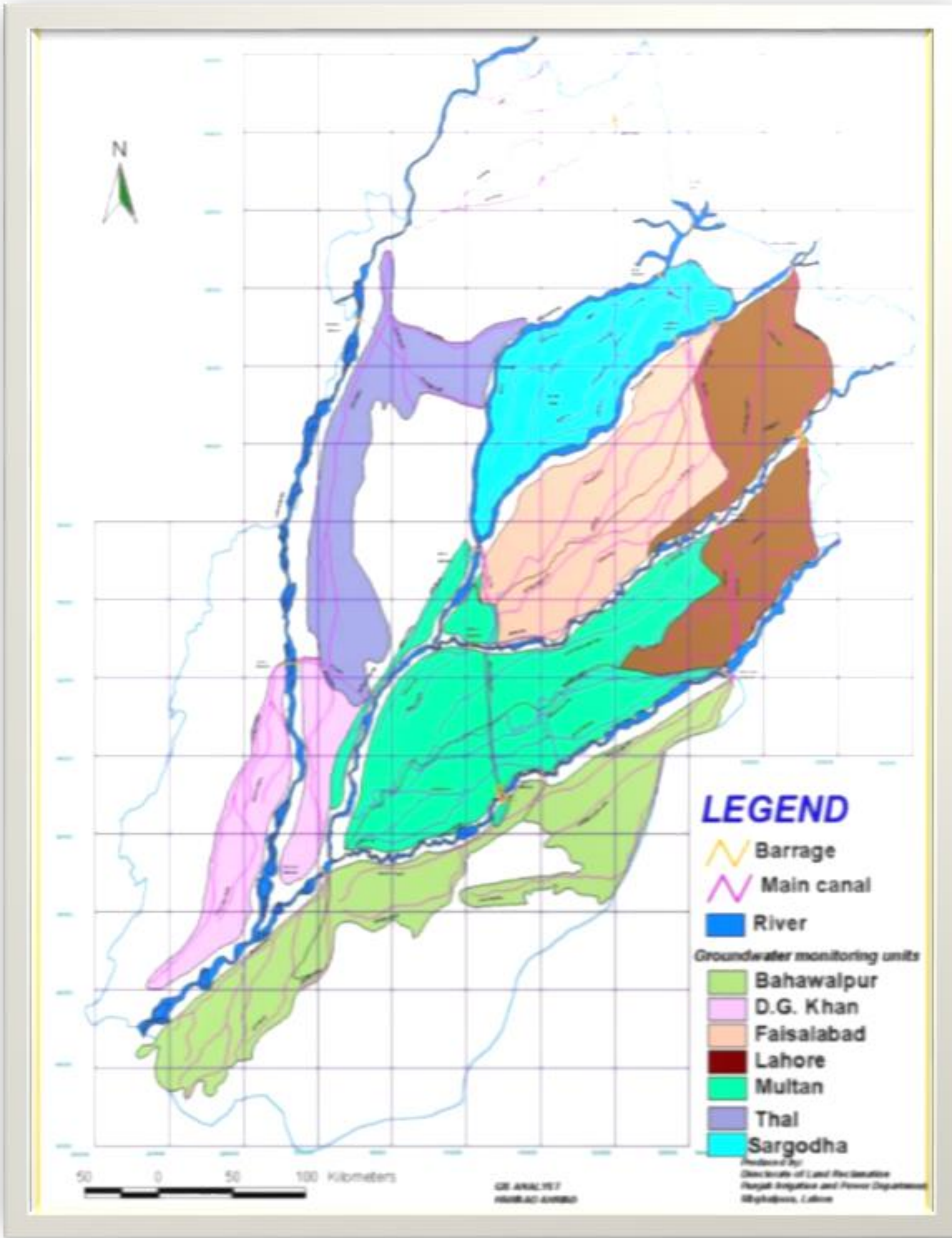


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Figure 3.2: Groundwater Monitoring Units in Punjab

Source: GOP, 2013

A multistage stratified sampling technique was used to select sample for the study. First of all three (3) districts of Punjab province i.e one from each cropping system/pattern keeping in view the issues of having saline (unfit) groundwater as well as fresh (fit) groundwater being used as a conjunctive source of irrigation, were selected randomly. In second stage, four (4) villages from each district i.e two (2) villages for saline (unfit) groundwater and two (2) villages for good (fit for irrigation) groundwater were selected randomly. Thus, a total of twelve (12) villages i.e six (6) villages for saline (unfit) and six (6) villages for non-saline (fit) ground water from these three districts ware taken for the study. In the third stage, 25 farmers from each village were selected randomly. In total three hundred (300) farmers i.e 150 farmers who were using saline (unfit) groundwater and 150 farmers who were using non-saline (fit) groundwater for the conjunctive use of irrigation purpose were interviewed for a comparative study (Table 3.4). A schematic diagram showing multistage stratified sampling frame is displayed in Figure 3.3.

The names of Districts and their corresponding villages covered under the study are detailed in Table 3.5. Location map of the studied districts and overall groundwater quality prevailing in these three districts are presented in Figures 3.4, 3.5, 3.6 and 3.7, respectively.

3.2 Data Collection Instruments/Tools

The following tools were developed for collection of required data.

i. Structured Questionnaire
ii. Checklists

A comprehensive structured questionnaire was prepared for data collection from individual farmers and then pre-tested in the field area. After necessary amendments observed during pre-testing, it was finalized. It consisted of all necessary indicators and modules as per requirement/ objectives of the study. Open ended checklists were also formulated to get information during focus group discussions and Stakeholder Consultation Sessions.

Table 3.4 : Sample Size

RICE – WHEAT		COTTON- WHEAT		MIXED		Overall	
District-1		District-2		District-3		3- Districts	
Saline G. water	Good G. water	Saline G. water	Good G. water	Saline G. water	Good G. water	Saline G. water	Good G. water
2 villages	2 villages	2 villages	2 villages	2 villages	2 villages	**6 villages**	**6 villages**
50 Farmers	50 Farmers	50 Farmers	50 Farmers	50 Farmers	50 Farmers	**150 Farmers**	**150 Farmers**
Total						**300 Farmers**	

Table 3.5 : Name of Districts and Villages

Crop Regions	Name of District	Name of Villages	
		Saline (Unfit) Groundwater	Non-saline(Fit) Groundwater
Rice - Wheat	Nankana Sahib	120 R.B	21 R.B
		182 R.B	87 R.B
Cotton – Wheat	Bahawalnagar	Gardariwala	Chaweka Uttar
		Sansaran	Wazirke Adlana
Mixed Crops	Faisalabad	271 R.B	414 G.B
		168 G.B	116 G.B

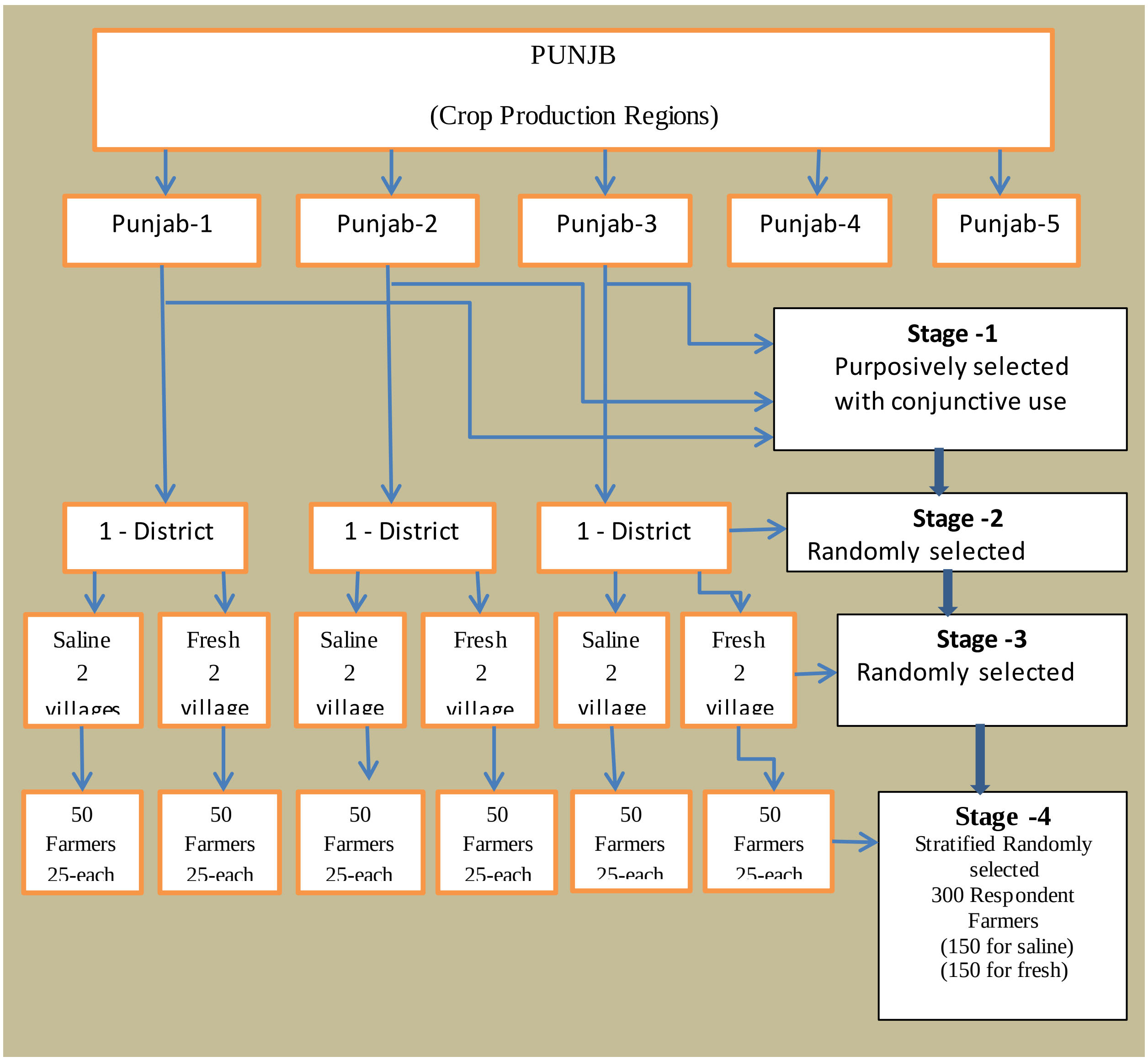

Figure 3.3: Schematic Diagram Showing Multistage Stratified Sampling

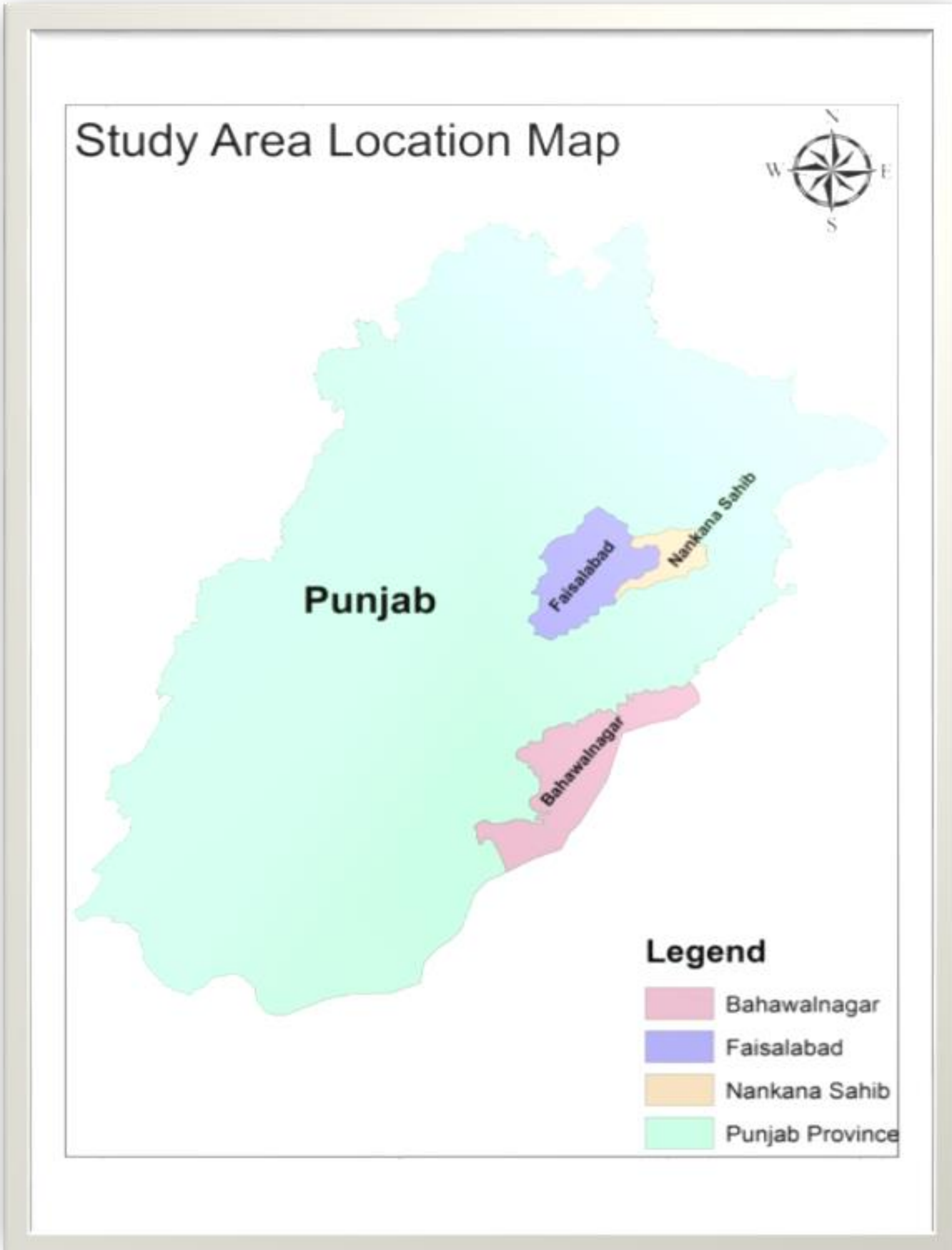

Figure 3.4: Study Area Location Map

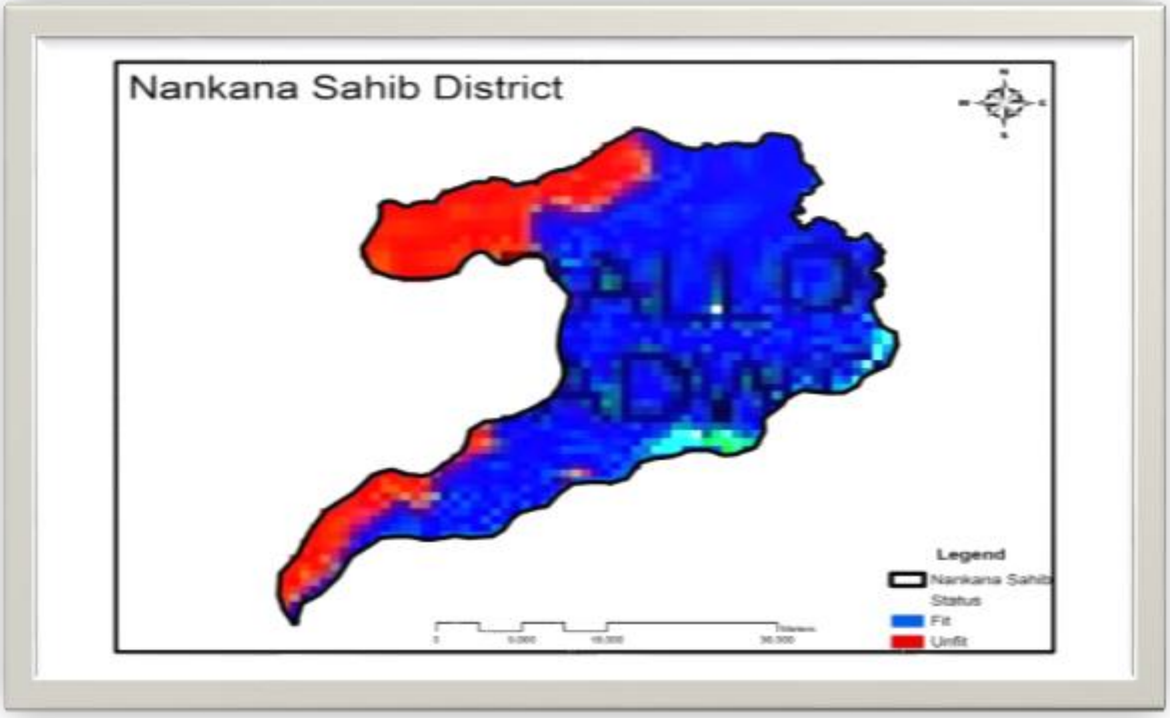

Figure 3.5: Groundwater Quality in District Nankana Sahib

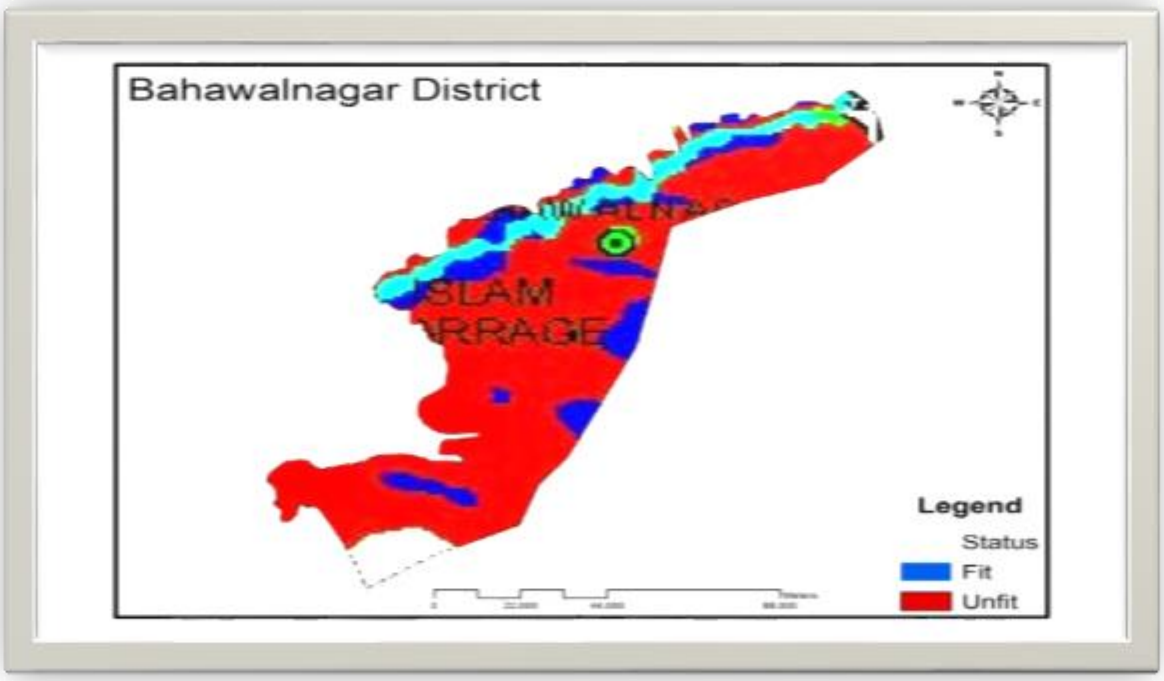

Figure 3.6: Groundwater Quality in District Bahawalnagar
Source : GOP, 2012

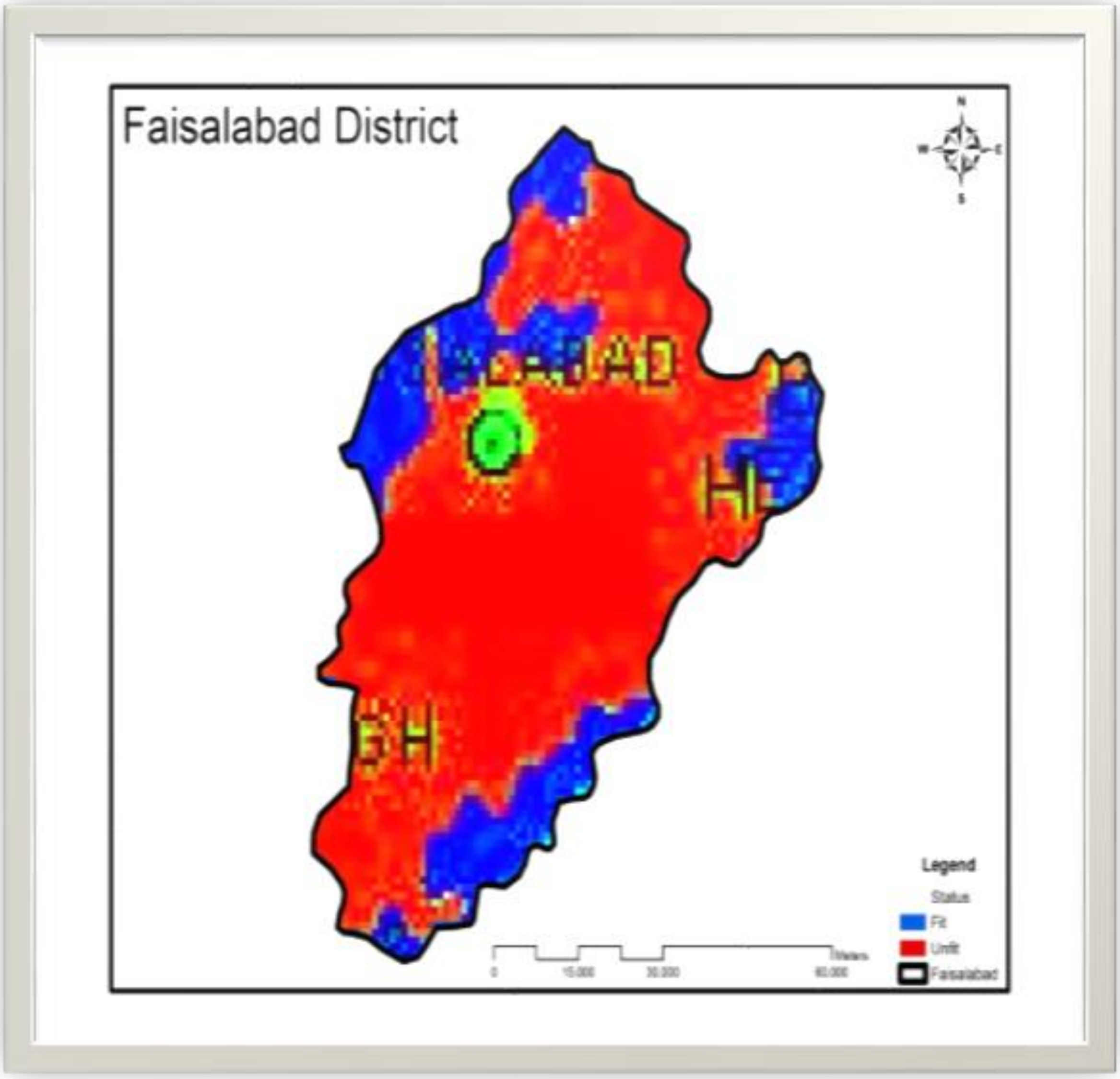

Figure 3.7: Groundwater Quality in District Faisalabad

Source : GOP, 2012

3.3 Nature and Sources of Data

Two types of data i.e Primary Data and Secondary Data were gathered for the study. The detail of each category is given below.

3.3.1 Primary data

A comprehensive field survey was conducted in the study area to collect information/ data. The data pertain to the crop year 2012-13. The following methods were used for primary data collection.

- Individual Farmers Survey
- Focused Group Discussions
- Stakeholder Consultation Sessions

Individual Farmers Survey

The sample farmers were selected keeping in view the requirements and necessary conditions of the study. The selected /sample farmers were contacted individually at their own farms and the required information/data were taken on the structured questionnaires. The interviews were conducted in a conducive environment and all necessary arrangements were made to ensure reliability and quality of data collected.

Focused Group Discussions

Focused group discussion is one of the methods used for collecting qualitative information. These qualitative interviews were also held for validation of data collected and perception of farmers regarding research issues and their possible solutions. This farmer/ community group was consisted of 8-10 farmers, representative of those particular villages. The information was collected on the checklist made for the purpose. This information was used along with various ways in the study. Two (2) focus group discussions in each district (mainly concerned for saline areas) were conducted.

Stakeholder Consultation Sessions

Stakeholder Consultation Sessions were made to seek more in-depth insight of the study. These sessions were held with key informants, experts and representatives of line departments/ research institutions.

Open ended discussions keeping in view the indicators of the study and checklist made for, were held. Their findings were also used for the study.

3.3.2 Secondary Data

Secondary data were obtained from various sources, which included as follows:

- Review of all available data/ literature
- Groundwater monitoring/ quality lists

All the available literature relevant to the study were reviewed and used for the study. Similarly groundwater quality monitoring lists as mentioned earlier were obtained from the Irrigation Department, Government of the Punjab, Pakistan and used for various stages of the study as per requirement.

3.4 Data Analysis and Analytical Approaches/ Techniques

Data analysis contained the following approaches:

- Overall analysis of fresh ground water and saline ground water area causing irrigation induced salinity/ land degradation under conjunctive water use environment.

- Economic analysis (major crops) of each cropping system, which included productivity difference, net margins, farm budgeting of major crops and computation of economic value of land degradation.

Major crops prevailing in the sample area were considered in the analysis. As major crops in the study area i.e Wheat, Cotton, Rice and Sugarcane comprised of about 71 percent, so these crops were analyzed in the study (Figure 3.8).

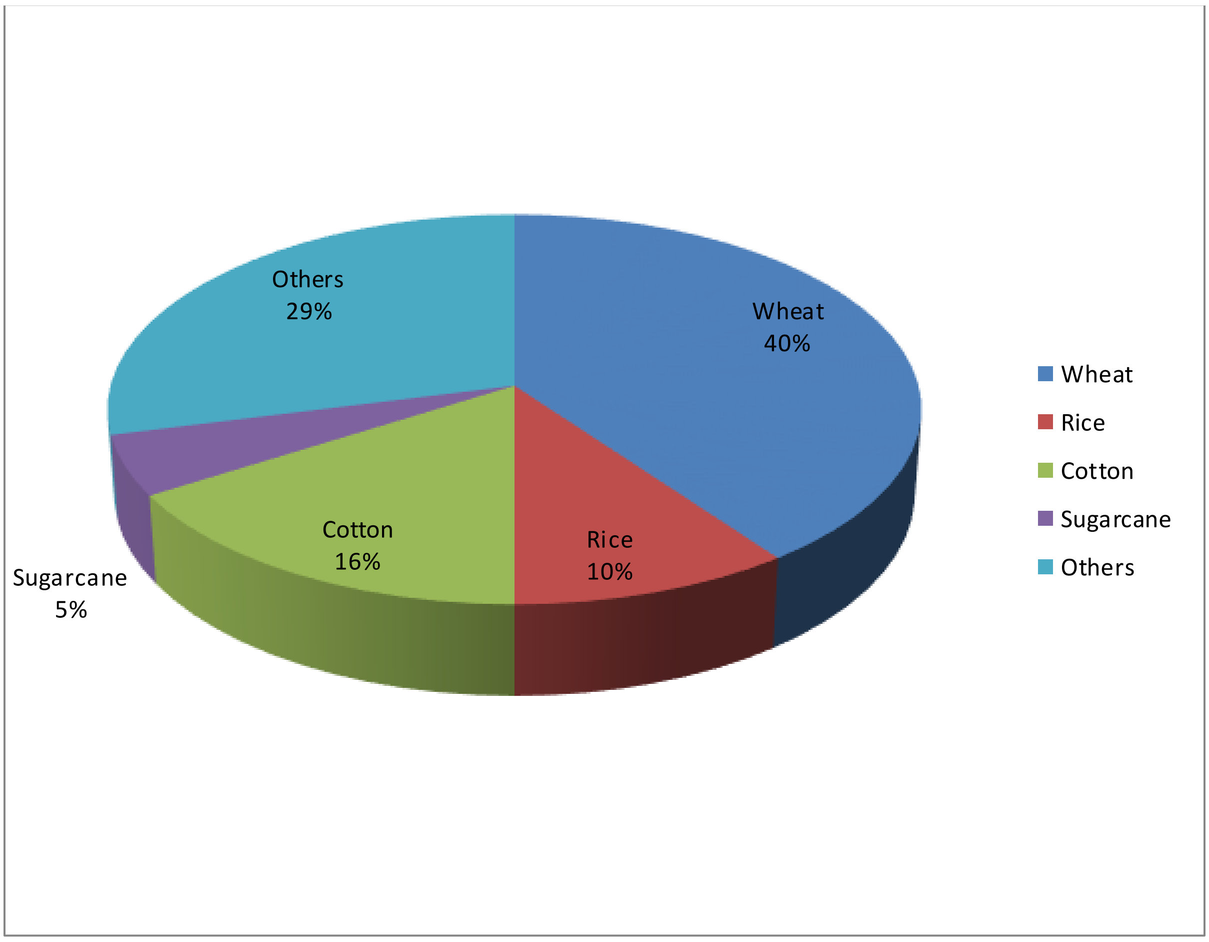

Figure 3.8: **Cropping pattern in Study Area**

Source: GOP, 2014

Analytical techniques used in the study with regard to each objective is summarized and presented below (Table 3.6).

Table 3.6: Objectives vs Analytical Techniques/ Methods

Objectives	**Analytical Methods**
i. To assess the effects of irrigation induced soil salinity on crop productivity, resource use and profitability.	○ Production Function approach for crop productivity analysis ○ Decomposed production analysis
ii. To compute the economic valuation of land degradation.	○ Decomposed production analysis ○ Tabular analysis approach Through productivity loss and resource use pattern (tillage, seed, fertilizer,

		labour use, irrigation, land rent, etc) from comparative analysis
iii.	To identify the socio-economic and physical factors affecting adoption of salinity control efforts taken by farmers.	Logit Model Analysis
iv.	To suggest policy guidelines for maximizing the economic returns under irrigation induced land degradation.	Based on research findings

The details of these analytical techniques are given as under:

3.4.1 Production Function Analysis

The choice of a functional form to accurately represent a given production relationship, depends upon the nature of that relationship (Griffiths *et al* .1993). Different production function with various regressions techniques were tested but the results of best-suited technique double-log/ Cobb-Douglas production function were best fit to the model. In agriculture sector, the Cobb-Douglas functional form of production functions is extensively employed to estimate the relationship of an output to inputs. It was proposed by Knut Wicksell and tested against statistical evidence by Paul Douglas and Charles Cobb in 1928.

Effects of soil salinity have to be clearly isolated from the other causes of production loss.
Several analytical approaches have been used to discern the pure impact of soil salinity from other factors of production. Pincock (1969) utilized whole farm budget to analyze the impact of salinity on net farm income. Moore *et. al.* (1974) used linear programming to estimate economic damage on multi-crop farms. Boster and Martin (1978) and Oyarzabad and Young (1978) have also applied variants of this approach. To analyze the long-term implications of leaching of salts, Yaron and Olian (1973) and Yaron (1985) have used dynamic programming models with irrigation of annual and perennial crops.

Hussain and Young (1985), Joshi (1987) and Joshi *et. al.* (1994) have estimated the crop losses due to soil salinity using the production function approach. While the former used electrical conductivity as one of the explanatory variables, the latter estimated the impact on crop yield using a dummy variable for soil salinity level. Joshi and Dayanantha Jha (1992) used different production functions for normal and saline soils and decomposed the pure effect of change in output due to soil salinity and resource use.

Cobb- Douglas and Translog production functions are commonly used in agriculture sector. So, the choice was made between these two types of functions. Model selection criteria i.e adjusted R^2, AIC and SIC was used to decide the appropriate model. These criteria suggested that Cobb-Douglas production was appropriate model. Thus, Cobb-Douglas production function was used in the study. The review of the literature too suggested that Cobb Douglas production function can also be used in similar studies. To study the impact of salt-affected soils on farm productivity, Singh *et al.*(1995), Kulkarni (2007) and Thiruchelvam and Pathmarajah (2003) used a Cobb-Douglas production function and separate production functions were estimated for different types of soils i.e normal and salt affected soil.

Similarly, in this study a Cobb-Douglas production function has been used and separate production functions were estimated for two types of soils i.e normal and salt affected soils to sort out the contribution of these effects. These have been specified in a log-linear form as follows:

For normal soil:

$$\text{Log } Y_1 = \log A_1 + b_1 \log X_1 + b_2 \log X_2 + ... + b_n \log X_n + \mu \quad (1)$$

For salt-affected soil:

$$\text{Log } Y_2 = \log A_2 + b'_1 \log X'_1 + b'_2 \log X'_2 + ... + b'_n \log X'_n + \mu' \quad (2)$$

There is no doubt that a production function is a physic relationship between inputs and output. The literature suggests that we can use the monetary value of inputs instead of physical inputs, especially when perfect market does not exist. A significant variation can be seen in value terms. The transportation cost also varied from farm to farm according to its location and distance from the market, which can brought further variation in input cost. Thus, input costs vary from farmer to farmer, but there was less difference/ variation in physical input use. So, inputs costs were used as independent variables. Similarly, there was less difference in yield of various crops among different farmers, so value of gross output was used as dependent variable as they sold their produce at different prices. Thiruchelvam and Pathmarajah (2003), Jehangir *et al.*(2003) and Raza (2008) used costs/ values in the model. Thus, the cost/value form was used in this study.

where :

Y= dependent variable i.e value of gross output obtained

X_i (i = 1,... n) = explanatory variables i.e seed, irrigation, fertilizer, labour, plant protection cost, etc.

A = scale parameter,

b_i(i = 1,...n) = output elasticity with respect to the ith explanatory variable.

As the analysis was made for major crops of the area i.e Wheat, Rice, Cotton and Sugarcane, the independent variables as per their importance/ relationship were used differently for these crops. These variables with regard to each crop are reflected below. In view of the importance of groundwater induced salinity, the impact/ relationship of both irrigation i.e canal and tubewell under each crop was observed.

The independent variables included for production function estimate for *Wheat* crop were as under:

LnX_1 = Land preparation & tillage cost (Rs.)

LnX_2 = Seed cost (Rs.)

LnX_3 = Fertilizer cost (Rs.)

LnX_4 = Tubewell Irrigation (Nos.)

LnX_5= Canal Irrigation (Nos.)

LnX_6 = Farm Yard Manure (Rs.)

LnX_7 = Plant protection chemicals (Rs.)

LnX_8 = Labour cost (Rs.)

The independent variables included for production function estimate for *Rice* crop were as under:

LnX_1 = Land preparation & tillage cost (Rs.)

LnX_2 = Seed cost (Rs.)

LnX_3 = Fertilizer cost (Rs.)

LnX_4 = Tubewell Irrigation (Nos.)

LnX_5= Canal Irrigation (Nos.)

LnX_6 = Labour cost (Rs.)

The independent variables included for production function estimate for *Cotton* crop were as under:

LnX_1 = Land preparation & tillage cost (Rs.)

LnX_2 = Seed cost (Rs.)

LnX_3 = Fertilizer cost (Rs.)

LnX_4 = Tubewell Irrigation (Nos.)

LnX_5= Canal Irrigation (Nos.)

LnX_6 = Plant protection chemicals (Rs.)

LnX_7 = Labour cost (Rs.)

The independent variables included for production function estimate for *Sugarcane* crop were as under:

LnX_1 = Land preparation & tillage cost (Rs.)

LnX_2 = Seed cost (Rs.)

LnX_3 = Fertilizer cost (Rs.)

LnX_4 = Tubewell Irrigation (Nos.)

LnX_5= Canal Irrigation (Nos.)

LnX_6 = Labour cost (Rs.)

Heteroscedasticity was not found in the data. However, autocorrelation and multicollinearity are basically the issues of time series data. But, some literature suggested (Kulkarni (2007) and Raza (2008) that multicollinearity may arise in cross sectional data. The Variance Inflation Factor (VIF) measures the impact of collinearity among the variables in a model. So, to avoid the possible cause of multicollinearity, the VIF test was done. The value of VIF that exceeds 10 is often regarded as indicating multicollinearity. The VIF values for all model analysis were less than 10. So, there was no issue of multicollinearity in the data. When values of R^2 and VIF are high for any of the variables in the model used, multicollinearity is probably an issue. When VIF is high, there is high multicollinearity.

3.4.2 Production Function Decomposition Analysis

To compute the economic valuation of land degradation in lieu of difference in productivity, Brzovic *et al.*(2011) used Production Function Approach i.e a Cobb-Douglas linear logarithmic form and obtained elasticity of output relative to each productive factor. The computation results included productive factor level, losses in production and factors elasticity.

Joshi and Jha (1992) used decomposition model to assess the impact of waterlogging and soil salinity on crop productivity and to estimate the difference in output due to soil degradation and input changes. Gummagolmath (2000) used decomposition model to estimate the difference in output due to soil degradation and input changes in Tungabhadra Project command area.

Other studies included i.e Singh *et al.*(1995), Kulkarni (2007) and Thiruchelvam and Pathmarajah (2003), which have used Cobb Douglas production function decomposition analysis in such sort of studies. So, Cobb Douglas production function decomposition analysis is hereby used for this study.

It becomes necessary to confirm whether there existed a structural break in the production relations that explained the output on degraded soils and normal soils. Therefore, to identify the structural break in the production relations that defined the yield levels on degraded soils and normal soils, a dummy variable with 1 for degraded soil and zero for normal soil was introduced in the production function of Cobb-Douglas setting for each crop.

Thus, to analyse the impact of salinity on resource use, Production Function Decomposition Analysis was made by taking the difference between Eqns. (2) and (1) and subtracting the same yield. By re-arranging terms, we obtained:

$$\text{Log}\ (Y_2/Y_1) = \log (A_2/A_1) + [(b'_1 - b_1) \log X_1 + (b'_2 - b_2) \log X_2 + \text{---} + (b'_n - b_n) \log X_n] + [b'_1 \log (X'_1 / X_1) + b'_2 \log (X'_2 / X_2) + \text{----} + b'_n \log (X'_n / X_n)] \qquad (3)$$

Equation (3) has measured the approximate difference in per acre output between normal and salt-affected soils. The sum of the first two bracketed components on the right-hand side indicated the land degradation effect. The third bracketed term measured the contribution of changes in input levels (resource use) between the two soil conditions.

3.4.3 Logit Model Analysis

To determine the factors influencing salinity control efforts taken by the farmers, Logit model analysis was used because our response variable is dichotomous qualitative. For the analysis of these data, the binary choice models are appropriate (Amemiya, 1981). Three common forms are the linear probability, logit and probit models. The linear probability model has several statistical deficiencies and is thus not considered suitable for this study (Capps and Kramer, 1985; Spector and Mazzeo, 1980).

The logit probability model is associated with the logistic distribution and the probit model assumes a standard normal distribution. These distributions are very similar to each other and thus applications of the logit and probit models have yielded similar results (Capps and Kramer, 1985; Epperson et al., 1988; Maddala, 1986). The selection of the model to use is generally a matter of convenience (Hanushek and Jackson, 1977).

Here under this study logit model was used and its general form is as under.

$$L_i = \ln (P_i / 1- P_i) = b_1 + b_2 X_i + u_i$$

The factors affecting salinity control measures adopted by individual farmers were personal, socio economic and physical factors. These included education, farming experience, ownership of agricultural land, value of land rent, having other sources of income and contacts with line departments.

The specification of the model used in the study is as under:

Dependent variable:	Salinity control measures adopted (if Yes =1, otherwise =0)
Independent variables:	
Education of farmers	No. of schooling years
Farming Experience	No. of years
Area ownership	Acres

(ratio of area owned and farm area)	
Land Rent	Rs.
Extent of salinity (as reported by farmers)	If highly saline =1, otherwise =0
Other sources of income (other than crops)	Having other sources of income =1, otherwise =0
Contacts with line Departments	If farmers contacted/ been contacted =1, otherwise = 0

The variable education, the years of schooling might have contribution in primary decision makers for adopting strategies. The status of land ownership would also have effects on adaptation. Higher value of land rent prevailing in different areas would affect the coping strategies. High extent of salinity would retard the adoptability as per expatiations. Farmers having other sources of income would not encourage investing more for reclamation of salt affected soils. Contact of farmers with line departments to seek help and guidance for remedial measures might also effect on strategies being adopted.

3.5 Summary

This chapter is based on the study area, sampling techniques, sample size, data sources and different methods used for data collection. The study was conducted in the selected areas of Punjab province of Pakistan, having irrigation-induced salinity affected soils (with saline ground water) and the area having good soils (fresh groundwater for conjunctive use) for its comparison.Three districts, a representative of major crop production regions namely Faisalabad, Nanakana sahib and Bahawalnagar were selected. Four villages from each district i.e two villages for saline (unfit) groundwater and two villages for good (fit for irrigation) groundwater were selected randomly. A total of twelve (12) villages i.e six (6) villages for saline (unfit) and six (6) villages for non-saline (fit) ground water from these three districts ware taken for the study. Twenty five farmers from each village were selected randomly. Three hundred (300) farmers i.e 150 farmers who were using saline (unfit) groundwater and 150 farmers who were using non-saline (fit) groundwater for the conjunctive use of irrigation purpose were interviewed.

Production Function approach and its decomposition analysis and Logit model analysis were used to address the objectives of the study.

CHAPTER 4 RESULTS AND DISCUSSION

This chapter elaborates results and discussions on various socio-economic and farm characteristics, agricultural productivity, returns and resource use pattern of major crops i.e Wheat, Rice, Cotton and Sugarcane which were analysed, in detail with regard to both categories (saline and normal groundwater areas) of sample farmers. Results of econometric analysis included Cobb-Douglas Production Function, Production Function Decomposition and Logit Model have also been discussed here. This chapter is divided into four parts as elaborated and reflected below:

Part – A: Socio-economic and Farm Characteristics

Part – B: Cost of Cultivation and Returns from major crops

Part – C: Cobb-Douglas Production Function Estimates and Decomposed Model Analysis

Part – D: Farmers perception on degradation externalities and Logit Model Analysis

Part – A: Socio-economic and Farm Characteristics

4.1 Socio- economic characteristics

The socio-economic characteristics included education, farming experience, demographic characteristics, primary occupation, household income from other than crops and its sources. These characteristics of sample respondents/ farmers of both comparative areas having saline (unfit) viz a viz non- saline (fit) groundwater areas have been captured and presented below.

4.1.1 Education, Farming Experience and Demographic Indicators

These characteristics i.e education which was computed as average schooling years, average age in years, household size including all male and female members and average farming experience are presented in Table 4.1. It revealed that these indicators in both areas i.e saline and normal groundwater areas were more or less the same.

Overall age of sample farmers was about 45 years in saline groundwater areas, while it was about 43 years in normal groundwater areas. Results on education status indicated that farmers (sample respondents) under both categories have completed 6 years of schooling. Farmers of saline areas have an experience of about 20 years of farming, whereas in case of normal areas, farmers have 19.5 years of experience. Average household size was 8.5 and 8.6 in saline and normal areas, correspondingly.

Table 4.1: Education, Farming Experience and Demographic Indicators

Characteristics	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Age (Years)	45.09 (13.21)	43.31 (13.46)
Education (schooling years)	6.74 (4.46)	6.67 (4.33)
Farming Experience (Years)	19.93 (10.87)	19.48 (10.91)
Household Size (Nos.)	8.49 (3.85)	8.56 (3.71)

Note : Figure in parentheses indicate standard deviation

4.1.2 Primary Occupation and Income Sources

Primary occupation of family members (male above 15 years) of both categories of households was analysed to seek the extent of engagement of these members in farming as primary occupation in both degraded (saline groundwater) and non-degraded (normal groundwater) lands. The proportion of other professions/ occupations adopted for income generation activities was also examined (Table 4.2).

It revealed that under saline areas about 50 percent of male family members having age of above 15 years of age were engaged in farming (crop production) as primary occupation, while about 30 percent of them were involved in other occupations for income generation. The corresponding figures in non-saline/ normal groundwater areas were 73 percent and 11 percent, respectively. This shows that in degraded areas (having saline/ unfit groundwater) less family members (23 %) as compared to non-degraded areas (having non-saline/ fit groundwater) were employed in crop production. More family members in saline areas i.e 19 percent higher as of normal areas have adopted other occupation for their earnings (Table 4.2).

As far as sources of income from other than crop production are concerned, about 70 percent of farmers in saline areas and 60 percent in non-saline areas were selling milk for income earning purpose. Under saline areas about 7 percent farmers were selling their tubewell water as source of income and 18 percent were using tractor as commercial purpose and whereas, in normal groundwater areas, these farmers were 5 percent and 8 percent, respectively. It reflects that in saline areas more farmers were engaged in other than crop earnings.

Table 4.2: Primary Occupation and Income Sources

(Percent)

Particulars	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Occupation (Family members of above 15 years of male)		
Farming as Primary Occupation	50	73
Other Occupations for income generation	30	11
Income Sources other than crops (Sample respondents)		
Sale of Milk	70	60
Sale of tubewell water	7	5
Tractor use	18	8

4.1.3 Household Income (other than crop)

Household income earned from other than crop production was also ascertained to see the dependence on other sources rather than crops, contained sale of milk, groundwater selling, use of tractor for commercial purpose and entrepreneur/ business activities in both studied areas.

Study results (Table 4.3) have shown that in saline areas, an amount of Rs. 10656 and Rs. 5759 were being earned from selling of milk and entrepreneurs/ services per month on an average per household, while the corresponding figures for normal areas were Rs.12915 and Rs.2197, respectively. It revealed that such overall non-crop income was Rs.17483 i.e (11 percent higher) in degraded lands as compared to normal areas of Rs.15703, showing more dependence on income other than crop production.

Table 4.3: Household Income other than Crops

(Rs.)

Characteristics	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Sale of Milk	10656 (14152.78)	12915 (17906.81)
Sale of tubewell water	294 (1176.08)	224 (1101.25)
Tractor use	775 (1879.74)	367 (1484.38)
Others (Services, entrepreneurs, pension, remittances, etc.)	5759 (9052.69)	2197 (6325.16)
Total	17483	15703

Note : Figures in parentheses indicate standard deviation

4.2 Farm Characteristics

This section presents land ownership, average land holding size, culturable waste, land rent and its value prevailing in both comparative study areas. It revealed (Table 4.4) that farm area in saline areas was 10.15 acres, while in normal (fit) groundwater areas it was 12.14 acres (about 16 percent higher) on an average. An imperative indicator is the effective cropped area in proportion of cultivated area under both categories. Study results have shown that in saline groundwater areas cropped area was 12.54 acres while, it was 21.55 acres in normal areas. Land rent and land value was higher i.e 41 percent and 27 percent, respectively in normal areas as compared to saline areas.

The proportion of sample farmers with respect to their land holding size i.e up to 5 acres, 5.1 to 12.5 acres, 12.6 to 25 acres and above 25 acre have also been calculated to observe proportionate of farm area under these categories in both normal and affected lands. The proportion of large farmers i.e 12.5 to 25 and above 25 acres was relatively higher i.e 6 percent and 4 percent, respectively in normal areas. Under small and medium categories i.e upto 5 and 5.1 to 12.5 acres, this proportion was higher (5 percent, for both farm sizes) in saline areas (Table 4.5).

4.2.1 Cropping Intensity

Cropping intensity in both areas was calculated by dividing total cropped area by total cultivated area. It was observed there was significant difference under cropping intensity of both areas. This was much low (129 percent) in saline (unfit) as compared to normal (fit) groundwater areas (182 percent) as reflected in Figure 4.1. The decrease in cropping intensity in saline areas over normal areas was 53 percent (significant at 1% of probability level). The findings of the study are in line with the findings of the studies conducted by Thiruchelvam, 2003 and Kulkarni, 2007.

Table 4.4: Farm Characteristics

Characteristics	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Area owned (acres*)	9.02 (10.23)	10.74 (11.47)
Farm area (acres)	10.15 (10.40)	12.14 (10.32)
Culturable waste (acres) (included area not available for cultivation)	0.51 (0.92)	0.34 (0.66)
Cultivated area (acres)	9.62 (8.71)	11.92 (9.85)
Cropped area	12.54 (14.21)	21.55 (22.01)
Land rent (Rs./acre)	17013 (4005.01)	28728 (4138.75)
Land value (Rs./acre)	998,167 (629970.81)	13,75949 (219610.88)

Note : Figures in parentheses indicate standard deviation

*: 1 hectare: 2.47 acres

Table 4.5: Farm Size

(Percent)

Farm size (acres)	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Up to 5	36	31
5.1 to 12.5	42	37
12.6 to 25	15	21
Above 25	7	11

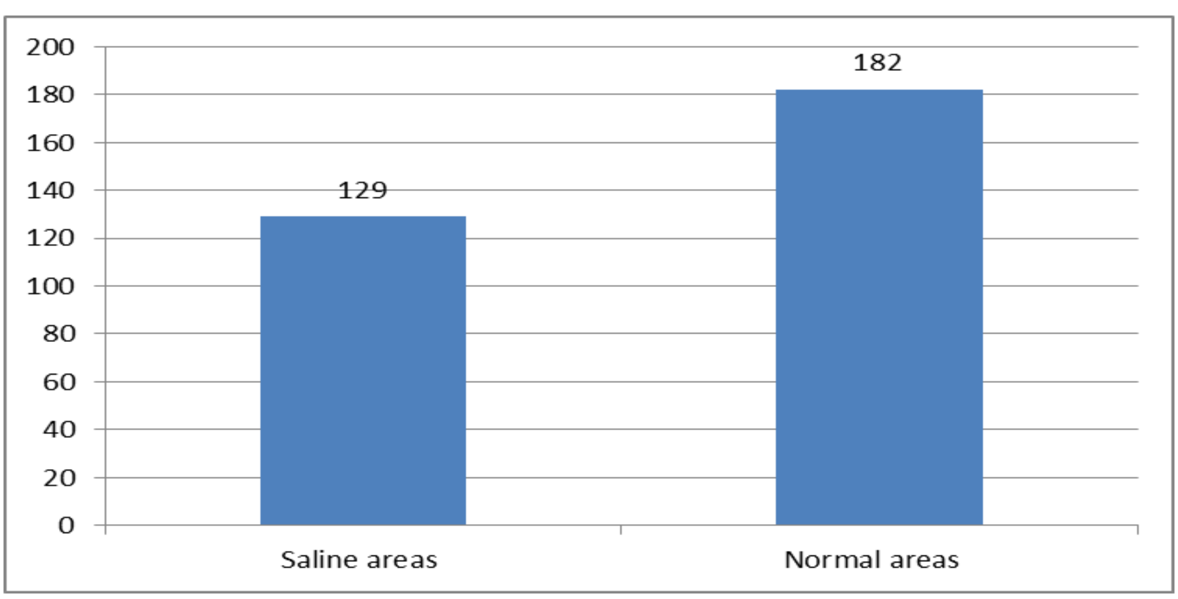

Figure 4.1: Cropping Intensity

*: Significant difference at 1% of probability level

4.2.2 Cropping Pattern

As mentioned in Chapter 3, that secondary sources have shown that major crops of the study area consisted of Wheat, Rice, Cotton and Sugarcane. However the actual prevailing area under various crops in both the study areas has been calculated.

These major four crops comprised of 75 percent and 80 percent of the total cropped area in saline as well as normal areas, respectively. The fodder crop was sown under 23 percent area in saline soils while it was at lower side (16 percent) in normal soils. Other crops (maize, oil seed, etc) constitute 2 percent and 4 percent in saline and normal areas, respectively (Figure 4.2 and 4.3). Study results reflect that farmers of both categories were sowing almost same crops with more or less same acreage except fodder crop which was higher (7 %) in saline areas due to growing of more fodder for their livestock and selling of milk as is evident from Table 4.2, wherein 10 percent more farmers in saline areas were selling milk as compared to normal areas. This finding having almost same cropping pattern under both areas under conjunctive use is in line with the study conducted by Jehangir *et al*, 2003.

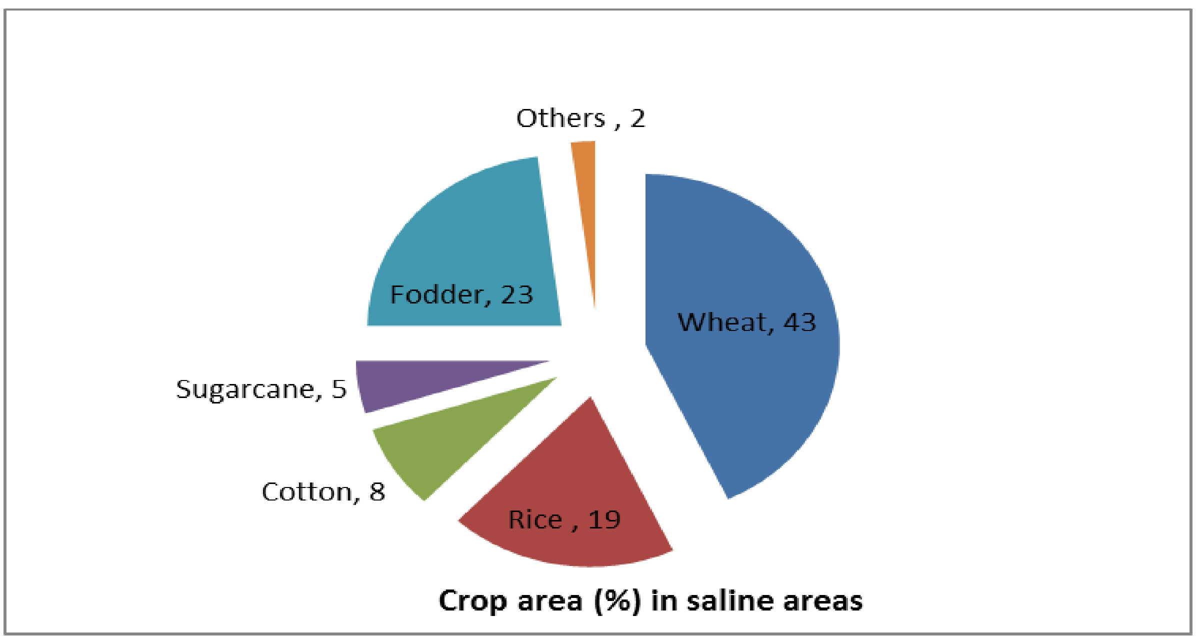

Figure 4.2: Cropping Pattern in saline areas

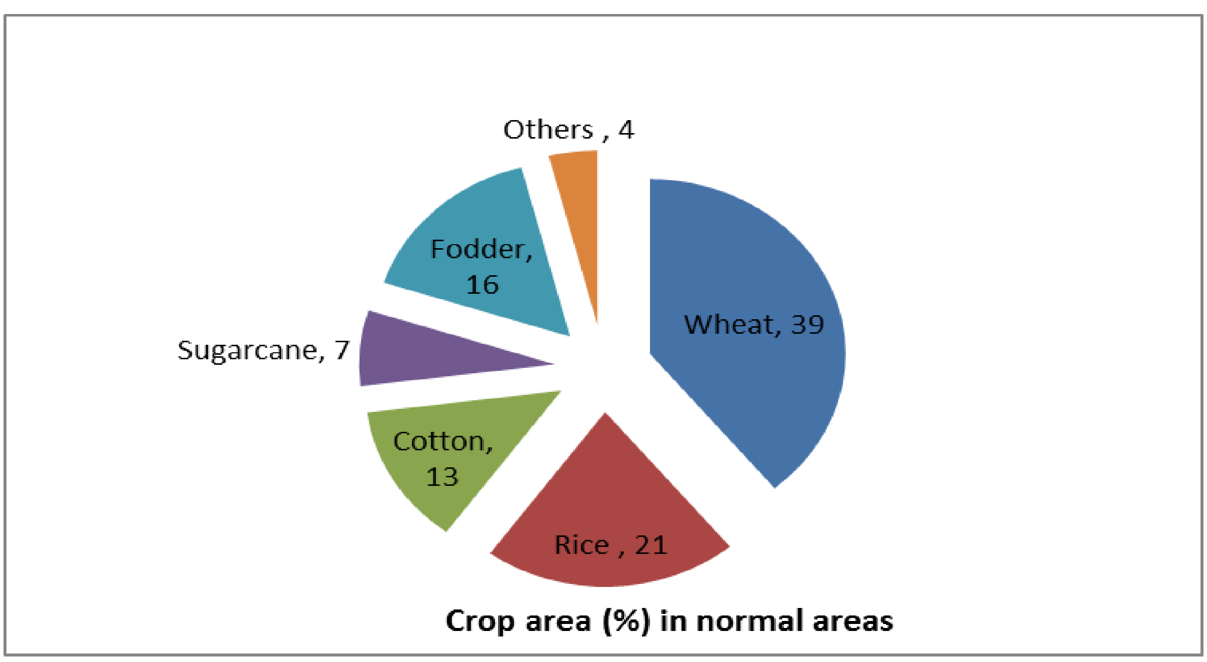

Figure 4.3: Cropping Pattern in normal areas

Part – B: Cost of Cultivation and Returns from major crops

4.3 Cost of Cultivation of Major Crops

As mentioned in methodology chapter that major crops of these districts/ cropping system i.e Wheat, Rice, Cotton and Sugarcane crops have been used for analysis purpose. The cost (variable costs) of production calculated for each crop is given below. These costs comprised of land preparation and tillage, seed, fertilizer, farm yard manure, plant protection, tubewell irrigation, labour cost and harvesting and threshing. Surface/ canal water cost has not been included because water charges are fixed/ flat rate irrespective of crop sown for both Rabi (winter) and Kharif (summer) seasons i.e Rs 65 and Rs. 85 per acre, respectively. In saline areas some farmers during the survey year used gypsum, so its minor cost has been included in the fertilizer cost.

4.3.1 Cost of Cultivation of Wheat crop

Cost of cultivation of wheat crop under both saline and normal areas has been calculated and given in Table 4.6. Overall cost in normal areas was higher (14 percent) as compared with saline areas. While tubewell irrigation and farm yard manure cost was higher by 5 percent and 14 percent respectively in case of wheat sown in saline areas. Due to less availability of canal water in saline areas, they have to depend more upon groundwater abstraction, which has increased tubewell irrigation cost. It was observed that farmers in saline areas were using less inputs as less productivity and low margins were obtained. This finding is in conformity with the findings of the study conducted by Singh (1995).

4.3.1 Cost of Cultivation of Rice crop

Overall cost of cultivation of rice crop in normal areas was higher (11 %), however cost incurred on seed and land preparation & tillage was almost same in both areas (Table 4.7). Tubewell irrigation cost obviously in saline areas was more (11 %) having less availability of surface water, so their dependence was more on tubewell water. Costs of fertilizer, farm yard manure and plant protection were lower in saline areas. .

Table 4.6: Cost of Cultivation of Wheat crop

(Rs. Per acre)

Cost items	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Land preparation and tillage	3389.47 (1038.11)	3738.74 (855.36)
Seed	1775.75 (280.12)	1868.27 (236.95)
Fertilizer	5676.03 (1631.05)	7652.51 (1115.82)
Farm yard manure	662.42 (759.05)	567.27 (903.26)

Plant Protection	373.18 (424.65)	652.13 (435.09)
Tubewell Irrigation cost	1895.36 (944.02)	1797.93 (719.91)
Harvesting and threshing	6180.56 (110.9.46)	6566.61 (763.97)
Labour cost	998.75 (248.16)	1061.50 (239.01)
Total cost	20951.47 (2969.47)	23904.96 (2565.17)

Note: Figures in parentheses indicate standard deviation

Table 4.7: Cost of Cultivation of Rice crop

(Rs. Per acre)

Cost items	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Land preparation and tillage	3759.49 (926.62)	3785.99 (942.98)
Seed	2867.28 (305.89)	2963.25 (387.70)
Fertilizer	6673.97 (1450.16)	7139.03 (1717.31)
Farm yard manure	142.25 (547.63)	537.42 (1154.81)
Plant Protection	675.31 (799.09)	886.09 (777.18)
Tubewell Irrigation cost	7709.15 (2576.11)	6845.51 (2457.72)
Harvesting and threshing	6404.93 (1523.21)	9223.53 (2135.16)
Labour cost	2041.55 (491.35)	2332.01 (415.03)
Total cost	30277.94 (4229.77)	33712.85 (4546.85)

Note: Figures in parentheses indicate standard deviation

4.3.1 Cost of Cultivation of Cotton crop

The results have shown that under cotton crop overall cost of cultivation was higher (35%) in normal areas as compared with saline areas (Table 4.8). Similarly cost against each category was also higher in normal areas except cost of farm yard manure. Both fertilizer and plant protection costs were too high (42 %) in normal areas. It shows that cotton crop gave fewer benefits/ returns in saline areas, thus farmers were using less quantity of inputs as compared to normal areas.

Table 4.8: Cost of Cultivation of Cotton crop

(Rs. Per acre)

Cost items	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Land preparation and tillage	2931.03 (753.24)	3310.11 (99067)
Seed	1685.40 (308.11)	1914.92 (426.51)
Fertilizer	5220.75 (1828.77)	7418.55 (1077.28)
Farm yard manure	377.50 (792.67)	260.70 (591.63)
Plant Protection	3389.68 (1379.68)	4847.05 (1174.25)
Tubewell Irrigation cost	3123.90 (1167.11)	3972.23 (1502.90)
Harvesting and threshing	4680.00 (1533.25)	7479.02 (1841.07)
Labour cost	2050.62 (370.70)	2458.72 (343.41)
Total cost	23458.87 (5236.48)	31681.28 (4248.73)

Note: Figures in parentheses indicate standard deviation

4.3.1 Cost of Cultivation of Sugarcane crop

In case of sugarcane crop, overall cost of cultivation in normal areas was also higher (20 %), whereas, tillage cost was more (6 %) in saline areas (Table 4.9). Cost on irrigation, labour and fertilizer was higher i.e 21 %, 13% and 25%, respectively in normal areas as compared to crop sown in saline areas.

Table 4.9: Cost of Cultivation of Sugarcane crop

(Rs. Per acre)

Cost items	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area

Land preparation and tillage	4100.51 (1193.05)	3856.48 (642.48)
Seed	12390.16 (922.04)	13315.02 (1776.77)
Fertilizer	5524.31 (1568.34)	6932.84 (1261.60)
Farm yard manure	843.14 (827.03)	965.04 (1283.15)
Plant Protection	516.18 (549.53)	728.07 (576.26)
Tubewell Irrigation cost	5505.78 (3035.37)	6672.48 (3218.31)
Harvesting and threshing	6786.76 (1226.90)	10799.64 (3732.22)
Labour cost	2174.51 (292.76)	2447.76 (314.79)
Total cost	37841.35 (4763.22)	45717.35 (5835.09)

Note: Figures in parentheses indicate standard deviation

4.4 Yield of Major Crops

The yield of these four major crops of the study area i.e Wheat, Rice, Cotton and Sugarcane have been calculated and the difference amongst them in relation to saline and normal areas have been observed. The study results have shown (Table 4.10) that yield was higher under all crops in normal areas. The difference was calculated as 23 percent more in wheat, 25 percent, 34 percent and 31 percent higher in case of Rice, Cotton and Sugarcane crops, respectively sown in normal areas (Fig 4.4). The reduction in yield of major crops was also observed by Kahlown and Azam (2002), Qureshi et al (2003) and Azhar (2005).

Table 4.10: Yield of Major Crops

(40 kgs per acre)

Crops	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Wheat	29.03 (4.64)	37.80 * (5.31)
Rice	26.73 (5.21)	35.89 * (5.76)
Cotton	16.53 (4.30)	25.09 * (5.77)
Sugarcane	446.80 (75.06)	653.84 * (94.18)

Note: Figures in parentheses indicate standard deviation

*: Significant at 1% of probability level

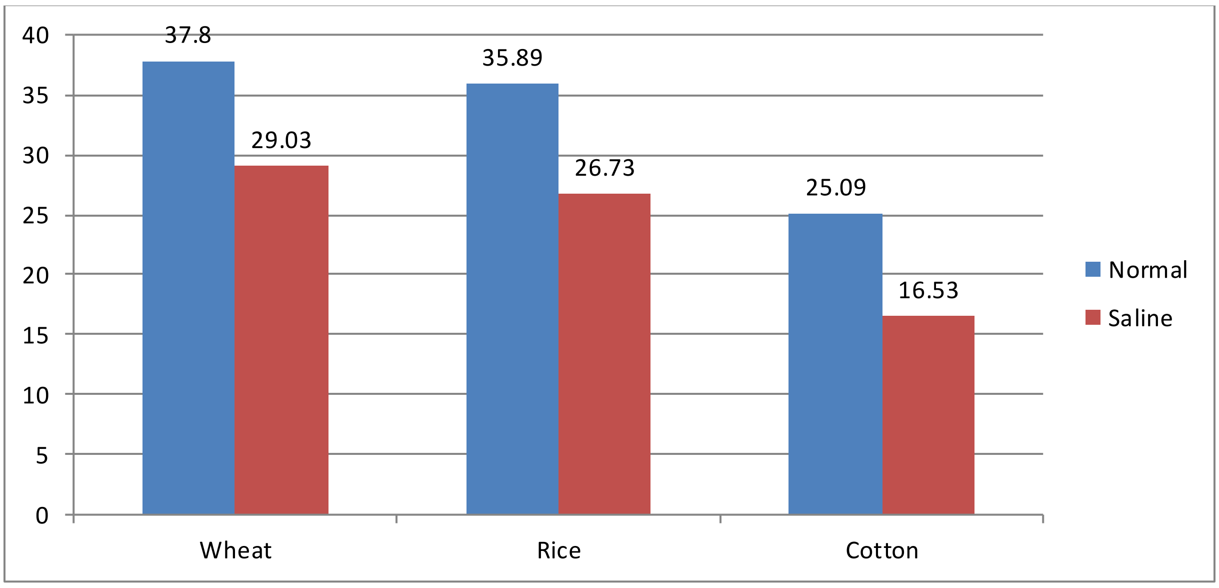

Figure 4.4: Yield of Major Crops

4.5 Net Returns

Returns are good indicator to estimate profitability and its ratio over cost. Total variable cost and gross income under each crop in both areas have been calculated to estimate net returns and cost incurred to produce one kg of that particular crop. Overall net returns, also called gross margin, were more in all crops sown in normal areas, whereas reduction in yield has reduced net returns in saline areas In saline areas loss in returns have been observed regarding each crop (Table 4.11, 4.12, 4.13 and 4.14).

It was observed that under wheat crop net returns i.e difference between gross returns and variable costs per acre were higher (64 percent), Rs. 26748 in normal areas as compared with Rs. 16268 in saline areas. Higher cost (13 percent) was incurred to produce one Kg of wheat in saline groundwater areas as compared to normal areas (Table 4.11).

Under Rice crop net returns were 67 percent higher in normal areas, while corresponding figures for Cotton and Sugarcane were 87 percent and 51 percent higher as of saline areas. Similarly to produce one Kg of Rice, Cotton and Sugarcane, cost incurred was 20 percent, 9 percent and 24 percent, respectively more in saline groundwater areas. Reduction in net returns was also observed by Jehangir *et al.* (2003) and Hussain *et al.* (2006).

Table 4.11: Returns in Wheat Crop

Particulars	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Total variable cost (Rs./acre)	20951	23904
Yield (40 Kgs/ acre)	29	38
Sale Price (40 kgs)	1283	1333
Gross Returns (Rs./acre)	37219	50654

Net Returns (Rs./acre)	16268	26748
Cost per kg (Rs.)	18.0	15.8

Table 4.12: Returns in Rice Crop

Particulars	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Total variable cost (Rs./acre)	30274	33713
Yield (40 Kgs/ acre)	27	36
Sale Price (40 kgs)	1944	1968
Gross Returns (Rs./acre)	52476	70857
Net Returns (Rs./acre)	22202	37145
Cost per kg (Rs.)	28.3	23.5

Table 4.13: Returns in Cotton Crop

Particulars	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Total variable cost (Rs./acre)	23458	31681
Yield (40 Kgs/ acre)	17	25
Sale Price (40 kgs)	2299	2438
Gross Returns (Rs./acre)	39074	60960
Net Returns (Rs./acre)	15615	29229
Cost per kg (Rs.)	34.5	31.6

Table 4.14: Returns in Sugarcane Crop

Particulars	Saline (Unfit) Groundwater area	Normal (Fit) Groundwater area
Total variable cost (Rs./acre)	37841	45717
Yield (40 Kgs/ acre)	447	653

Sale Price (40 kgs)	156	162
Gross Returns (Rs./acre)	69659	105588
Net Returns (Rs./acre)	31818	59870
Cost per kg (Rs.)	1.8	2.7

Part – C: Cobb-Douglas Production Function Estimates and Decomposed Model Analysis

4.6 Estimation of Cobb-Douglas Production Function

As explained in Material and Methods section that separate production function for saline and normal soils have been computed then decomposition model was analysed to assess the productivity difference due to salinity and resource use and to measure the losses in saline / degraded soils. Estimates of Cobb Douglas production function pertaining to each crop i.e Wheat, Rice, Cotton and Sugarcane has been carried out and their relationship with various inputs fit for the model are summarised below (Table 4.15, 4.16, 4.17, 4.18)

Gross value of output obtained for each crop has been taken as dependent variable, as explained earlier in section 3.4.1. The coefficient of multiple determination (R^2) in case of normal soil was 61 percent , 45 percent, 41 percent and 38 percent under wheat, rice , cotton and sugarcane crops respectively. While the corresponding figures in saline areas were 56 percent, 39 percent, 70 percent and 43 percent for wheat, rice , cotton and sugarcane crops, respectively. The results are in line with similar studies of Singh *et al.*(1995) and Kulkarni (2007).

4.6.1 Cobb-Douglas Production Function Estimates for Wheat crop

In this model under Wheat crop, important variable costs i.e tillage, seed, fertilizer, farm yard manure, plant protection and labour, while both types of irrigation i.e canal and tubewell irrigation in their respective number of applications have been included as independent variables. For both categories of farms, these variables have been included as natural log form.

Model results have shown that value of coefficient of determination (R^2) was 0.56 in case of saline areas, while it was 0.61 under normal areas. This shows that 56 percent variation in dependent variable was attributed by independent variables in saline areas, whereas in normal areas this variation was observed as 61 percent (Table 4.15). In all crops, the coefficient of tubewell irrigation was not statistically significant in saline groundwater areas. This result was in accordance with *priori* expectations, as saline groundwater has not significant impact on productivity and implicitly on vale of output.

Table 4.15: Cobb-Douglas Production Function Estimates for Wheat crop

Variables	Parameters	
	Saline (unfit) Groundwater area	Normal (fit) Groundwater area
Constant	12.79	10.41
Tillage	0.190**	-0.190**

	(0.090)	(0.093)
Seed	0.118 (0.119)	0.342** (0.142)
Fertilizer	0.242*** (0.090)	0.372*** (0.126)
Tubewell Irrigation	-0.012 (0.055)	0.128** (0.059)
Canal irrigation	0.195*** (0.066)	0.085 (0.067)
Farm Yard Manure	0.004 (0.064)	0.093 (0.084)
Plant Protection	0.058 (0.073)	-0.010 (0.084)
Labour	0.763*** (0.208)	0.233 (0.281)
R^2	0.56	0.61
Adjusted R^2	0.49	0.52
F- value	7.6	5.92

Note: Figures in parentheses indicate standards errors of their respective coefficients

*: Significant at 10% of probability level , **: Significant at 5% of probability level

***: Significant at 1% of probability level

The F- values i.e 7.6 (saline areas) and 5.6 (normal areas) depict that overall model was significant. The estimated coefficients for tillage, fertilizer, canal irrigation and labour were significant at less than 10 percent of probability level, in saline areas. The coefficient of tubewell irrigation was negative. It revealed that 1 percent increase in tubewell irrigation could reduce the gross value of output by 0.012 percent. Under normal areas wheat, the coefficient of tillage, seed fertilizer and tubewell irrigation were statistically significant. However, the coefficient of tillage was negative as over tillage was being used. The cost of labour varies from area to area, so labour cost has been used instead of working hours as these have less variation. In normal soil, farmers employ more labour with the expectation to get better yield, that's why coefficient is positive which means increase in labour would result in increase in yield.

4.6.2 Cobb-Douglas Production Function Estimates for Rice crop

The model results (Table 4.16) have exhibited that value of coefficient of multiple determination (R^2) was 0.39 in case of saline areas, whereas it was 0.45 under normal areas. This shows that more variation (45 percent) in dependent variable was observed by independent variables in normal areas, as compared with saline areas (45 percent). F-values (4.5 and 5.1) have also shown that overall model was significant in both categories.

The coefficients of tillage, canal irrigation and labour were significant in saline areas. Seed, fertilizer and tubewell irrigation coefficients were positive but not statistically significant. On the other side in normal areas, the coefficients of seed, fertilizer, tubewell irrigation and labour were statically significant (Table 4.16).

4.6.3 Cobb-Douglas Production Function Estimates for Cotton crop

In cotton crop model, an important variable i.e plant protection (chemical sprays) have been included for both categories of farms. The coefficients of tillage, canal irrigation and labour were significant at 10 percent or below probability level, under saline areas. Coefficients of seed, fertilizer, tubewell irrigation and plant protection were positive but not significant (Table 4.17).

In normal areas, coefficients of seed, fertilizer, tubewell irrigation, tillage, canal irrigation and plant protection were significant at below 10 percent of probability level.

Table 4.16: Cobb-Douglas Production Function Estimates for Rice crop

Variables	Parameters	
	Saline (unfit) Groundwater area	Normal (fit) Groundwater area
Constant	6.20	8.16
Tillage	0.228 * (0.199)	0.056 (0.074)
Seed	0.178 (0.238)	0.227** (0.133)
Fertilizer	0.118 (0.094)	0.216** (0.066)
Tubewell Irrigation	0.059 (0.083)	0.145** (0.052)
Canal irrigation	0.128 * (0.072)	0.052 (0.079)
Labour	0.312 * (0.178)	0.210* (0.122)
R^2	0.39	0.45
Adjusted R^2	0.31	0.37
F- value	4.50	5.05

Note: Figures in parentheses indicate standards errors of their respective coefficients

*: Significant at 10% of probability level , **: Significant at 5% of probability level

***: Significant at 1% of probability level

Table 4.17: Cobb-Douglas Production Function Estimates for Cotton crop

Variables	Parameters	
	Saline (unfit) Groundwater area	Normal (fit) Groundwater area
Constant	4.89	3.55
Tillage	0.352*** (0.134)	-0.008 (0.091)
Seed	0.256	0.223**

	(0.210)	(0.129)
Fertilizer	0.130 (0.128)	0.411** (0.227)
Tubewell Irrigation	0.167 (0.127)	0.603** (0.137)
Canal irrigation	0.185 * (0.095)	0.096 (0.103)
Plant Protection	0.172 (0.123)	0.486*** (0.141)
Labour	0.317 * (0.173)	0.300 (0.318)
R^2	0.70	0.41
Adjusted R^2	0.63	0.34
F- value	10.68	5.94

Note: Figures in parentheses indicate standards errors of their respective coefficients

*: Significant at 10% of probability level , **: Significant at 5% of probability level

***: Significant at 1% of probability level

The coefficient of plant protection has shown that plant protection measures (chemical sprays) were more effective (statistically significant) in normal areas. The coefficient of tillage was negative, which reflects that one percent increase in tillage cost will decrease 0.01 percent of gross value of output. Over tillage practices were being applied in these areas (Table 4.17).

The values of coefficient of multiple determinations (R^2) were 0.70 and 0.41 in saline areas and normal areas, respectively. The F-values of 10.7 (saline areas) and 5.9 (normal areas) revealed that overall model was statistically significant.

4.6.4 Cobb-Douglas Production Function Estimates for Sugarcane crop

Under Sugarcane crop model, the plant protection (chemicals) variable was not included as very few farmers used this measure in both categories of farms. The values of R^2 for saline areas and normal areas were 0.43 and 0.38, respectively. F- values (5.6 and 5.2 respectively for saline and normal areas) show overall significant of the model (Table 4.18).

In saline areas the coefficients of tillage, fertilizer, canal irrigation and labour were statically significant, whereas the coefficients of seed, tubewell irrigation, canal irrigation and labour were significant in normal area in sugarcane. Under normal areas coefficients of both types of irrigation i.e tubewell and canal were negative, which inferred that any increase in these irrigations will have negative effect on productivity. Thus, over irrigations were being applied in normal groundwater areas.

Table 4.18: Cobb-Douglas Production Function Estimates for Sugarcane crop

Variables	Parameters	
	Saline (unfit) Groundwater area	**Normal (fit) Groundwater area**
Constant	6.74	2.44
Tillage	0.202** (0.087)	0.043 (0.130)
Seed	0.095 (0.293)	0.373** (0.165)
Fertilizer	0.157** (0.076)	0.141 (0.112)
Tubewell Irrigation	0.037 (0.063)	-0.101** (0.053)
Canal irrigation	0.126 * (0.076)	-0.198** (0.086)
Labour	0.221 * (0.112)	0.563*** (0.177)
R^2	0.43	0.38
Adjusted R^2	0.35	0.29
F- value	5.60	5.23

Note: Figures in parentheses indicate standards errors of their respective coefficients

*: Significant at 10% of probability level , **: Significant at 5% of probability level

***: Significant at 1% of probability level

4.7 Decomposition Model Analysis

The results presented so far revealed that, there was significant difference in the yield of these crops between degraded and normal soils. The various sources contributing to yield difference between degraded and normal soils were estimated through decomposition analysis.

It became necessary to confirm whether there existed structural break in the production relations that explained the output in degraded and normal soils. Therefore, to identify the structural break in the production relations that defined the yield levels in degraded and normal soils, a dummy variable (nature of soil) was introduced in the production function in Cobb-Douglas settings. The significant dummy coefficients for such crops implied the structural break in production relationship between the degraded soils and normal soils

The dummy coefficients for wheat (-0.119***), Rice (-0.309***), Cotton (-0.097*) and Sugarcane (-0.333***) in case of normal soils versus saline soils were significant at 1 and 10 percent probability level (Table 4.19, 4.20, 4.21 and 4.22).

The decomposition analysis was used to know the contribution of land degradation and various inputs to the productivity difference between degraded and normal soils using the production function estimates and geometric mean values of inputs and output. The productivity difference attributed was decomposed into its constituent sources namely, productivity difference due to soil degradation and that due to the difference in input use.
The results of decomposition analysis for each crop are presented in Table 4.23.

These results have shown that contribution of soil degradation to the productivity difference was higher than that of input use. It was 10 percent, 33 percent, 11 percent and 32 percent under Wheat, Rice, Cotton and Sugarcane crops, respectively, while the difference due to inputs use was 4.5,1, 4 and 6 percent, respectively. Overall productivity difference/ reduction was 14.2, 33.2, 14.8 and 38.6 percent in case of Wheat, Rice, Cotton and Sugarcane crops, respectively.

Table 4.19: Structural Break in Production Relations of Wheat crop

Variables	**Parameters** **Normal (fit) Groundwater area VS Saline (unfit) Groundwater area**
Constant	7.88
Tillage	0.059* (0.031)
Seed	-0.038 (0.121)
Fertilizer	0.344*** (0.099)
Tubewell Irrigation	0.027 (0.051)
Canal irrigation	0.035 (0.061)
Farm Yard Manure	-0.095* (0.051)
Plant Protection	-0.028 (0.068)
Labour	0.063

	(0.215)
Dummy	-0.119*** (0.042)
R^2	0.37
Adjusted R^2	0.29
F- value	4.74

Note: Figures in parentheses indicate standards errors of their respective coefficients

*: Significant at 10% of probability level , **: Significant at 5% of probability level

***: Significant at 1% of probability level

Table 4.20: Structural Break in Production Relations of Rice crop

Variables	**Parameters** **Normal (fit) Groundwater area VS Saline (unfit) Groundwater area**
Constant	7.35
Tillage	0.102* (0.062)
Seed	0.172 (0.113)
Fertilizer	0.191*** (0.053)
Tubewell Irrigation	0.081* (0.044)
Canal irrigation	-0.048 (0.051)
Labour	-0.026 (0.091)
Dummy	-0.309*** (0.036)
R^2	0.45
Adjusted R^2	0.43
F- value	20.02

Note: Figures in parentheses indicate standards errors of their respective coefficients

*: Significant at 10% of probability level , **: Significant at 5% of probability level

***: Significant at 1% of probability level

Table 4.21: Structural Break in Production Relations of Cotton crop

Variables	**Parameters**

	Normal (fit) Groundwater area VS Saline (unfit) Groundwater area
Constant	2.036
Tillage	0.019 (0.080)
Seed	0.199* (0.116)
Fertilizer	0.116 (0.110)
Tubewell Irrigation	0.302** (0.094)
Canal irrigation	0.116 (0.075)
Plant Protection	0.311*** (0.098)
Labour	-0.140 (0.257)
Dummy	-0.097* (0.056)
R^2	0.59
Adjusted R^2	0.56
F- value	18.05

Note: Figures in parentheses indicate standards errors of their respective coefficients

*: Significant at 10% of probability level , **: Significant at 5% of probability level

***: Significant at 1% of probability level

Table 4.22: Structural Break in Production Relations of Sugarcane crop

Variables	Parameters Normal (fit) Groundwater area VS Saline (unfit) Groundwater area
Constant	3.72
Tillage	0.128* (0.074)
Seed	0.300** (0.144)
Fertilizer	0.112* (0.059)
Tubewell Irrigation	0.044 (0.041)

Canal irrigation	-0.053 (0.056)
Labour	0.370*** (0.123)
Dummy	-0.333*** (0.042)
R^2	0.69
Adjusted R^2	0.66
F- value	31.5

Note: Figures in parentheses indicate standards errors of their respective coefficients

*: Significant at 10% of probability level , **: Significant at 5% of probability level

***: Significant at 1% of probability level

Table 4.23: Decomposition of Total Difference in Productivity Between Normal Versus Saline Soils

(Percent per acre)

Sources of change	**Crops**			
	Wheat	**Rice**	**Cotton**	**Sugarcane**
Saline (unfit) Groundwater	-9.7	-32.9	-11.2	-32.4
Changes in input use	-4.5	-1.09	-3.6	-6.2
Total change	-14.2	-33.18	-14.8	-38.6

Joshi and Jha (1992) used decomposition model to estimate the difference in output due to soil degradation and input changes. The estimated model accounted for 88 per cent of the difference in mean income between normal soils and salt affected soils, and 84 percent between normal and waterlogged situations.

Gummagolmath (2000) also used decomposition model to estimate the difference in output due to soil degradation and input changes in Tungabhadra Project command area. The estimated model accounted for 67.85 per cent of the difference in paddy productivity between normal soils and moderately saline soils, and 54.13 per cent between normal and waterlogged soils. The problem of salinity accounted for 63.17 percent of the difference in productivity between normal and moderately saline soils.

4.8 Economic Losses of Degradation

Study results have shown that there were various types of difference i.e reductions in saline soils over normal soils, like reduction in productivity, land rent, land value, cropping intensity, etc. These reductions are ultimately transformed into monetary losses in lieu of per acre in the study area and Punjab province in totality.

These calculations have shown (Table 4.24) that economic loss per acre per annum of sample farmers was Rs.30238. This was significant amount/income per acre which was not being received by the farmers annually. So, this was the value of land degradation which has to be paid by the farmers in saline areas.

If these economic losses were measured in overall study areas, it became about Rs.31.5 million per year and similarly these losses were Rs. 232591 million which comes to US $ 2326 million per year in Punjab's agrarian (crop production) economy (Table 4.24). Externality cost including reclamation expenditure had not been included in this cost. These losses were also calculated by World Bank (2006) and IGRAC (2009).

Table 4.24: Economic Losses of Degradation

Particulars	Losses (Rs.)
Productivity Difference*	13847
Land Rent Difference	10714
Cropping intensity Difference	5677
Total Difference/ Loss (per acre per annum)	30238
Total loss in study area (Rs. Million per annum) (Total 1043 acres)	31.5
Total loss in Punjab (Rs. Million per annum) (7,692,000 acres)**	232591
Total loss in Punjab (US $*** million)	2326

*= Decomposition Analysis (average of cropping system)

**= Relevant w.r.t irrigated (conjunctive) and extent of unfit (50 %) of groundwater (GOP, 2014).

***= 1 US $ = 100 Pak Rs.

Part – D: Farmers Perception on Degradation Externalities and Logit Model Analysis

4.9 Farmers Perception on degradation and Irrigation Induced Externalities

Respondent farmers were asked about various issues like their perception about soil quality, strategies adopted to combat degradation issues, contact with line departments, reasons not for adopting control measures and their consequences on agriculture, human beings and animals. Their response pertaining to each segment is presented below.

4.9.1 Perception about soil quality

Farmers were asked about status of soil quality of their farms with various time periods i.e currently, 5 years ago, 10 & 20 years ago. It was evident (Table 4.25) that majority of the farmers (50 percent) reported that their land was highly saline and remained more or less same during all these time periods. About 15 percent claimed that high salinity was occurred in 70 percent of agricultural land during all periods. It revealed that this issue was intact for the last 10 years with the same extent of salinity as explained by respondent farmers.

4.9.2 Strategies Adopted to Combat Degradation Issues

Farmers in Pakistan opt a wide range of measures to mitigate salinity. These measures are mostly related to water management, crop choice, cultural practices and the application of chemical and biotic amendments. The choice of measure depends largely on farm characteristics and the experience of the farmer and fellow farmers (Aslam and Paratahpar, 2006).

Table 4.25 : Perception about Soil Quality

(Response in %)

Period	High Salinity (% of farm land)			
	Up to 30 %	31 to 50 %	51 to 70 %	Above 70 %
Current	16	50	18	16
5 Years ago	17	49	19	15
10 Years ago	16	50	18	16

In study area similar measures were being adopted by the farmers. These were classified regarding irrigation related, use of chemical ameliorates with saline water and gypsum, cultivation and crop choice and use of organic and green manuring recommended for irrigation induced degraded lands. Farmers were also adopting such strategies as control measures. So, they were asked about adoption and effectiveness of these strategies. Among these strategies, a very common practice was cleaning and lining of minors and water courses in which farmers have played an affective role and were involved in these activities at various levels. About 93 percent of farmers told they have always ensured cleaning of their water courses which remained an effective tool (91% claimed) to enhance surface water availability (Table 4.26).

Other coping strategies used by the farmers were the use of chemical ameliorates with saline water (25%), use of gypsum (42%), increased seed rate (65%), deep ploughing (69%) , increased use of organic manure (56%), land levelling (65%), deep ploughing (69%) and change in cropping pattern/ rotation (47%). Land levelling was not adopted as laser levelling, but ordinary tillage levelling was being practised.

Effectiveness of these adopted strategies was also ascertained. Only 6 percent of the farmers, who had adopted a measure of change in crop rotation, claimed it an effective practice. The use of gypsum remained one of the effective strategies as 92 percent of the adopters reported it. Similarly response of effectiveness against other adopted measures is listed below in Table 4.26.

Table 4.26: Strategies Adopted By Farmers To Combat Degradation Issues

(Percent)

Strategy	Measure	Adopted	Effective
Irrigation	Cleaning/ lining of minors /water courses to increase surface water	93	91
	Use of chemical ameliorates with saline water	25	35
Cultivation and crop choice	Change in cropping pattern/ crop rotation	47	6
	Increased seed rate	65	25
	Deep Ploughing	69	30
	Land leveling	65	95
Organic matte and gypsum use	Increased use of organic manure	56	39
	Use of gypsum	42	92

4.9.3 Reasons for Non-Adoption of Coping Strategies

The perusal of study shows (Table 4.27) that farmers have recorded certain reasons due to which they did not take up certain measures. Major reason was very poor quality of groundwater used for conjunctive purpose, as reported by 96 percent farmers. Thus, it was the major hindrance in using coping strategies. When they were probed about the usage of gypsum in saline soils for better results, they were of the opinion that gypsum could not give appropriate results in highly saline/ unfit irrigation water. This finding is in accordance with the study carried out by GOP (2012). The study finding revealed that most successful interventions of the project were gypsum application for rehabilitation of salt affected land followed by implement pools and community tube wells. Gypsum application results were better where good quality irrigation especially ground water was available. Rehabilitation of land process in Sargodha district was slow due to non-availability of adequate quantity of good quality irrigation water. Under marginal and poor quality water it could not give better results.

Other reasons included, having other income sources (66 percent reported) causing more dependence on non-crop sources, individual action alone was not sufficient (98 %), poor economic conditions (89 %), high cost of reclamation was required (97 %) so could not afforded it. About 97 percent farmers were of opinion that government was not providing any sort of facilitation in the form of subsidies, or some incentives for such degraded lands so by individual actions such issues could not be overcome. About 69 percent said that they had no technical knowledge for using coping measures. Similar findings were observed by Kulkarni, 2007.

Table 4.27: Reasons for Non-Adoption of Coping Strategies

Reasons	Response (%)

Groundwater quality is too much poor	96
Had other income sources	66
Poor economic conditions	89
High capital required for reclamation	97
Individual actions alone not sufficient	98
Lack of incentives and subsidies by Govt.	97
Lack of technical know-how	69

4.9.4 Perception of Land Degradation Issues and Consequences on Agriculture

Farmer's perception regarding consequences of such salinity/ degradation on agriculture was solicited. These indicators were development of hard pan, less crop yield, decline in land value, increased dependence on non-crop resources, family members inclined to shift to cities for their earnings, shifted resources to other fertile lands, etc.

The major response was of low crop yield (98%) and decline in land value (99%) and increased dependence on non- crop earnings (97%). Only 27 percent farmers reported that they were leasing out their land, because no one was ready to lease in such affected lands. Their response on other issues is reflected in Table 4.28. These perceptions are of similar as observed by Kulkarni, 2007.

Table 4.28: Perception of Degradation Issues and Consequences on Agriculture

Degradation Indicator	Response (%)
Development of hard pan	88
Salt accumulation and poor germination/ yellowing and crop failure in early stages	93
More inputs usage (seed, fertilizer, chemicals, etc)	37
More incidence of pests and diseases	18
Low crop yield	98
Decline in land value	99
Shifted resources to other fertile land	46
Increased dependence on non- crop earnings	97
Family members inclined/ shifting to cities for earnings	67
Leasing –out affected land	27

4.9.5 Perception of Health and Environmental Issues

Farmer's identification on critical environmental problems being caused due to such irrigation induced (saline groundwater) salinity in terms of sources of their drinking water, human health, sources of animal/ livestock drinking water, animal health and vegetation, were investigated and summarized below.

Sources of Human and Animal Drinking Water

As groundwater of the study area was saline and not good for drinking purpose of human beings and animals/ livestock. Thus, farmers were inquired about sources of drinking water being used for both human beings and their livestock. It was examined that about half of the communities/ households (49 percent) of the study area were having improved drinking water supply, while 42 percent of them were fetching water from some improved sources like, hand pumps and tubewells installed in fresh water areas and 9 percent were using the saline groundwater (Table 4.29).

Table 4.29: Sources of Human and Animal Drinking Water

Particulars	Response (%)
Sources of human drinking water and its effects	
Water supply	49
Fetching	42
Groundwater	9
High incidence of water borne diseases, if saline water used	97
Sources of animal/ livestock drinking water and its effects	
Canal water pond	33
Groundwater	29
Water supply	38
Occurrence of animal diseases if saline groundwater used	95

Effect on Human and Animal Health

Farmers opined that sometimes water supply was stopped due to operational and maintenance problems then they had to rely on saline groundwater or fetching water from some improved sources like, hand pumps and tubewells installed in fresh water areas. Their productive time was lost in such sort of activities and they had to face more diseases particularly water borne. About 97 percent farmers reported that in such cases, more chances of prevalence of water borne diseases were occurred (Table 4.29).

Similarly in case of animal drinking, wherein about 29 percent farmers were using saline groundwater for animal drinking purpose, they highlighted (95 percent) that animals had to face more diseases in such situation (Table 4.29).

Effect on vegetation

To identify the direct effects of such salinity on vegetation was difficult. However the information gathered from farmers revealed that some types of weeds or shrubs have become permanent feature of these salt affected fallow lands. The flora and fauna of these degraded lands were being disturbed. These findings are in conformity with findings of the studies carried out by Parshad and Singh (1997) and Thiruchelvam (2003).

4.9.5 Institutional Contacts

Farmers were asked whether they contacted or were contacted by various institutions like line departments (agriculture, irrigating), research institutions, development projects and *local khal panchayat* regarding their issues. No response was obtained regarding research institutions and development projects.

Results have shown (Table 4.30) that 50 percent farmers have contacted with departments, while only 11 percent farmers have been contacted by departments. About 4 percent farmers reported that they had contacted local *khal panchayat*, while 12 percent farmers said local *khal panchayat* has contacted them for the solution of their sufferings.

Table 4.30: Institutional Contacts

(Percent)

Department/ agency	Contacted by Farmers	Contacted by Agency/ Departments
Line departments (Agriculture, Irrigation, etc)	50	9
Local Khal Panchayat	4	12
Contacted none	46	79

4.10 Estimation of Logit Model Analysis

Logit model analysis has been used to see the relationship of various socio-economic and topographic factors on farmer's adoptability of various combating measures to minimize/ overcome the issues of irrigation induced land degradation.

These factors included education, their farming experience, land ownership and value of land rent, farmers' perception in qualitative response regarding extent of salinity with their lands, having other sources of income other than crop sector and contacts with line departments.

Model analysis have shown (Table 4.31) that variables of land ownership, value of land rent, and contacts with departments have made positive and significant effect, whereas education of farmers and their farming experience has not found significant relationship. The variable of having other sources of income with *priori* expectations has not shown significant connection because due to their other sources, there was less need to rely on crop income, so did not adopt such measures.

Salinity was overlong problem of the areas being used saline groundwater for irrigation. Farmers have been using various coping measure from time to time. They used coping strategies when the land use has become at threshold level, because the coping/ combating measures were of high cost/ unaffordable to them. Fresh/ surface water was needed to leach down the salts. In view of scarcity of fresh surface water and time consuming it was not being practiced. Thus, extent of salinity variable is significant but negative.

Similar results have also been observed by Barungi and Maonga, 2011, in studying adoption of soil management technologies by smallholder farmers in central and southern Malawi.

Table 4.31: Results of Logit Model Analysis

Variables	Parameters
Constant	1.473
Education (No. of schooling years)	0.019 (0.48)
Farming Experience (No. of years)	0.023 (0.021)
Area owned (ratio of area owned and farm area)	0.120 * (0.051)
Land Rent (Rs.)	0.002 * (0.001)
Extent of salinity (1,0)	-1.405 ** (0.464)
Other sources of income (1,0)	0.152 (0.459)
Contacts with line Departments (1,0)	1.043 * (0.441)
Log likelihood	138.95

Note: Figures in parentheses indicate standard errors of their respective coefficients
*: Significant at 5% of probability level **: Significant at 1% of probability level

4.11 Focused Group Discussions

The purpose of these group discussions were validation of data collected and to take insight regarding their issues and to seek help to gather information/ data for the study as mentioned in Chapter 3. These discussions were mainly concerned with saline areas.

They were asked about current cropping pattern being adopted in the area, resource use pattern including use of inputs pattern and the yield obtained from major crops. They were of the opinion that they had to face about 25 to 40 percent reduction in yield regarding Wheat, Rice, Cotton and sugarcane crops as compared with normal areas and subsequently the costs were not reduced.

They were facing a shortage of surface water as their areas were located at tail end, so less canal water was available as compared to the areas located at head end reach, which were normally having good soils and more productivity. They were adopting various methods and techniques to increase surface water, but in vein because groundwater quality was very poor. They reported that their surface water may be enhanced as compared to good areas because they had fresh groundwater to supplement it. Other way, community tubewell may be installed by the government in fresh ground water areas and that water may be added to surface water to increase fresh water supply in the area. They also explained that due to the poor quality of groundwater not only crops were being suffered but it had created very bad impact on human beings as well as animals. When human beings and animals used to take such water, the possibility of water borne diseases increased so they had to suffer due to these diseases.

They also reported that water thefts were being occurred, and influential people were involved to do it with the support of line departments. Local khal Panchayat system were functional in the area but was not effectively working, was reported by them.

Farmers were of the opinion that special package may be launched by the government wherein the supply of fresh water might be ensured as per requirement of crops/ area and some sort of subsidies on inputs, and supply of gypsum on nominal charges or free may also be included in that package.

When they were asked about the price of surface water i.e water charges being paid by them, they explained that they were ready to pay more than even 2 to 5 times more as compared with prevailing rates, if canal water supply could be enhanced as per crop requirement. This finding is in accordance with the study recently conducted a study by Bell *et al.*(2014) entitled " Reimagining cost recovery in Pakistan's irrigation system through willingness-to-pay estimates for irrigation water from a discrete choice experiment" funded by International Food Policy Research Institute (IFPRI).

4.12 Stakeholder Consultations

Stakeholder consultations were held with representatives of line departments, research institutes, etc, to take insight of area, land degradation issues and possible solutions to overcome such irrigation induced land degradation. The representatives of line departments briefed about shortage of canal water, and were unable to check pilferage/ water theft. They explained that when this malpractice was to be checked, they were transferred to other place due to the interruption of influential persons.

When they were asked about the addressing of farmer community issues , they said that staff was busy most of the time in administrative and official routine work, so they had no time and resources for solution of farmers' sufferings. Regarding effectiveness of Khal Panchayat and Private Mode canal system, they also told system was not so efficient as was thought due to political interference in the country.

It was also shared that if the cost/ water charges of canal water may be enhanced, then substantial amount may be gained as a revenue. This increased revenue may be used for O&M needs of irrigation system which cost is being escalating. In this connection, studies conducted by Haq, 1998 and IPD, 2009 were also shared and participants were agreed that minimum increase should be in accordance with findings of the study. The study highlighted that stagnating water rates and declining collections are also a source of concern in the context of the cost recovery gap. The historic data on assessments and collections shows that recovery levels have dropped to 70-75 percent during the 1990s, as compared to 80-85 percent recoveries during the 1980s. The historic trends of increase in O&M expenditure Vs water rates are presented below (Table 4.32).

Table 4.32: Increases in O&M Expenditure Vs Water Rates

(Percentage in Nominal Terms)

Period	Increase in O&M Expenditure	Increase in Water Rates
1970s	290	25
1980s	180	50
1990s	140	95
2000s	70	-

Source: Haq, 1998 and IPD, 2009

4.13 Summary

This chapter pertaining to Results and Discussion has been divided into four parts; (a) Socio-economic and Farm Characteristics, (b) Cost of cultivation and returns from major crops, (c) Cobb-Douglas Production Function estimates and Decomposed Model analysis and (d) Farmers perception on degradation externalities and Logit Model analysis.

The socio-economic characteristics included education, farming experience, demographic, primary occupation, household income from other than crops and its sources. Farm characteristics comprised of status of land ownership, average land holding size, culturable waste, land rent and its value prevailing in both comparative study areas having saline (unfit) viz a viz non- saline (fit) groundwater areas have been captured.

Cost of cultivation, yields, gross margins/ returns with regard to four major crops of the study area i.e Wheat, Rice, Cotton and sugarcane under both categories of farms were analysed in detail. With the help of econometric analysis, Cobb-Douglas production function estimates, the relationship of various independent variables on dependent variable (gross value of output) was analysed. Decomposed model analysis helped to compute the economic value of such degraded lands.

Farmer’s perception on degradation and irrigation induced externalities entailed soil quality, strategies adopted to combat degradation issues, contact with line departments, reasons not to adopting control measures and its consequences on agriculture, human beings and animals, were recorded. Views of focused group discussions and stake holder consultations have also been presented. Results of Logit Model analysis have shown the relationship of various socio-economic and topographic factors on farmers adoptability of various combating measures to minimize/ overcome the issues of irrigation induced land degradation.

CHAPTER 5 SUMMARY

This chapter includes summary of the study, its conclusions, limitations of the study and future policy implications. These are briefed as below:

5.1 Summary

Increased agricultural productivity is central towards sustainable economic growth, alleviating poverty and ensuring food security in the country. Irrigation plays a significant role in the growth of agriculture particularly the crop sector. Irrigation constitutes a mixture of both canal and underground water. The role of groundwater is more important than surface water for irrigation purpose because the dependence on groundwater has been increased which ranged from 65 percent (in the head end) to 90 percent (tail end areas).

In Punjab province of Pakistan about 75 percent of the irrigated area is dependent on the pumped/ ground water. The saline groundwater when applied for irrigation purpose causes more salinity in the area which limits the agricultural production and deteriorates the quality of agricultural land. This problem is becoming a serious threat to the sustainability of irrigated agriculture in the country particularly in the Punjab province, wherein more than 50 percent of the groundwater is saline causing a huge secondary salinization in the irrigated soils.

Overall focus of this research was to assess effects of land degradation on farm productivity and returns, to estimate the economic value of such degradation and to identify various factors affecting the adoption of irrigation induced salinity control measures by farmers.

The study was conducted in the selected areas of Punjab province of Pakistan, having irrigation-induced salinity affected soils (with saline ground water) and the area having good soils (fresh groundwater for conjunctive use) for its comparison. Amongst five crop production regions/ cropping systems of Punjab province, three regions namely Rice-Wheat, Cotton- Wheat and Mixed crops constituted 80 percent of total cropped area of the province and fall under conjunctive water use environment. These three cropping systems were selected purposively for the study which have both saline (unfit) groundwater as well as fresh (fit) groundwater which is being used as a conjunctive source of irrigation. A multistage stratified random sampling technique was used to select sample for the study. Three districts one from each cropping systems selected, were taken randomly. Four villages from each district i.e two villages for saline (unfit) groundwater and two villages for good (fit for irrigation) groundwater were selected randomly. Thus, a total of twelve villages i.e six villages for saline (unfit) and six villages for non-saline (fit) ground water ware taken for the study. Twenty five farmers from each village were selected randomly. In total three hundred (300) farmers i.e 150 farmers who were using saline (unfit) groundwater and 150 farmers who were using non-saline (unfit) groundwater for the conjunctive use of irrigation purpose were interviewed. Production Function approach and its decomposition analysis and Logit model analysis was used to address objectives of the study.

Primary occupation of the family members (male above 15 years) of the farmers household was analysed to know upto that extent these members were engaged in farming as primary occupation in both degraded (saline groundwater) and non-degraded (normal groundwater) lands. About 50 percent of male family members of above 15 years of age were engaged in farming (crop production) as primary occupation, while about 30 percent of them were involved in other occupations for income generations in saline areas. The corresponding figures in non-saline/ normal groundwater areas were 70 percent and 10 percent, respectively. In degraded areas (having saline/ unfit groundwater) less family members (23 percent) as compared to non-degraded areas (having non-saline/ fit groundwater) were employed in crop production.

As far as sources of income other than crop production were concerned, about 70 percent of farmers in saline areas and 60 percent in non-saline areas were selling milk for income earning purpose. Under saline areas about 7 percent farmers were selling their tubewell water as source of income and 18 percent were using tractor as commercial purpose and whereas, in normal groundwater areas, these farmers were 5 percent and 8 percent, respectively.

An amount of Rs. 10656 and Rs. 5759 were being earned from selling of milk and entrepreneurs/ services per month on an average per household, while the corresponding figures for normal areas were Rs.12915 and Rs.2197, respectively. It revealed that such overall non-farm (crop) income was Rs.17483 i.e (11 percent higher) in degraded lands as compared to normal areas of Rs.15703 showing more dependence on it.

Farm area in saline areas was 10.15 acres, while in normal (fit) groundwater areas it was 12.14 acre (about 16 percent higher) on an average. An imperative indicator is the effective cropped area in proportion of cultivated area under both categories. Study results have shown that in saline groundwater areas cropped area was 12.54 acres while, it was 21.55 acres in normal areas. Land rent and land value was higher 41 percent and 27 percent, respectively in normal areas.

Cropping intensity was much low (29 percent) in degraded saline (unfit) groundwater areas as compared to normal areas (182 percent). The decrease in cropping intensity in saline areas over normal areas was 53 percent.

Cost of production of wheat crop under both comparative areas i.e saline and normal, revealed that it was higher (14 percent) in normal areas as compared with saline areas. While, tubewell irrigation and farm yard manure cost was high i.e 5 percent and 14 percent, respectively in case of wheat sown in saline areas. Under rice crop in normal areas, overall cost was higher (11 %), however cost incurred on seed and land preparation & tillage was almost same in both areas. Tubewell irrigation cost obviously in saline areas was more (11 %) having less availability of surface water, so their dependence was more on tubewell water. Costs of fertilizer, farm yard manure and plant protection were lower in saline areas. Cost of production of Cotton was higher (35%) in normal areas as compared with saline areas. Similarly cost against each category was also higher in normal areas except cost of farm yard manure. Both fertilizer and plant protection costs were too high (42 %) in normal areas. In case of sugarcane crop, overall cost of production in normal areas was also higher (20 %), whereas, tillage cost was more (6 %) in saline areas. Cost on irrigation, labour and fertilizer was higher i.e 21 %, 13% and 25%, respectively in normal areas as compared to crop sown in saline areas.

Yield was higher under all crops in normal areas. The difference was calculated as 23 percent more in wheat, 25 percent, 34 percent and 31 percent higher in case of Rice, Cotton and Sugarcane crops, respectively sown in normal areas.

Net returns i.e difference between gross returns and variable costs per acre under wheat crop were higher (64 percent). Higher cost (13 percent) was incurred to produce one Kg of wheat in saline groundwater areas as compared to normal areas. Under Rice crop, net returns were 67 percent higher in normal areas, while corresponding figures for Cotton and Sugarcane were 87 percent and 51 percent higher as of saline areas. Similarly to produce one Kg of Rice, Cotton and Sugarcane, the cost incurred was 20 percent, 9 percent and 24 percent, respectively more in saline groundwater areas.

Under Cobb Douglas production function estimates, the coefficient of multiple determination (R^2) in case of normal soil was 61 percent, 45 percent, 41 percent and 38 percent under wheat, rice, cotton and sugarcane crops, respectively. While the corresponding figures in saline areas were 56 percent, 39 percent, 70 percent and 43 percent for wheat, rice , cotton and sugarcane crops, respectively.

Decomposition model results revealed that contribution of soil degradation to the productivity difference was higher than that of input use. It was 10 percent, 33 percent, 11 percent and 32 percent under Wheat, Rice, Cotton and Sugarcane crops, respectively, while the difference due to inputs use was 4.5 percent, 1 percent, 4 percent and 6 percent, respectively. Overall productivity difference/ reduction was 14.2 percent, 33.2 percent, 14.8 percent and 38.6 percent in case of Wheat, Rice, Cotton and Sugarcane crops, respectively.

Economic loss per acre per annum of sample farmers was Rs.30238. This was significant amount/income per acre which was not being received by the farmers annually. So, this was the value of land degradation which has to be paid by the farmers in saline areas. If these economic losses were measured in overall study areas, it became about Rs.31.5 million per year and similarly these losses were Rs. 232591 million which comes to US $ 2326 million per year in Punjab's agrarian (crop production) economy. Externality cost including reclamation expenditure had not been included in this cost.

Farmers were adopting some strategies as a control measures for degraded lands. Among these strategies, a very common practice was cleaning and lining of minors and water courses in which farmers have played an affective role and involved in these activities at various levels. Other coping strategies were the use chemical ameliorates with saline water (25%), use of gypsum (42%), increased seed rate (65%), deep ploughing (69%) , increased use of organic manure (56%), land levelling (65%), deep ploughing (69%) and change in cropping pattern/ rotation (47%). Land levelling was not as laser land levelling, but ordinary tillage levelling was being practised. Effectiveness of these adopted strategies was also ascertained. Only 6percent of the farmers, who had adopted a measure of change in crop rotation, claimed it an effective practice. The use of gypsum remained one of the effective strategies as 92 percent of the adopters reported it.

Farmers have recorded certain reasons due to which they did not take up certain measures/ strategies for combating degradation issues. Major reason was very poor quality of groundwater used for conjunctive purpose, as reported by 96 percent farmers. Thus, it was major hindrance in using coping strategies. Other reasons included, having other income sources (66 percent reported) causing more dependence on non-crop sources, individual action alone was not sufficient (98 %), poor economic conditions (89 %), high cost of reclamation was required (97 %) so could not afforded it. About 97 percent farmers were of opinion that government was not providing any sort of facilitation in the form of subsidies, or some incentives for such degraded lands so by individual actions such issue could not be overcome. About 69 percent said that they had no technical knowledge for using coping measures.

Farmer's perception regarding consequences of such salinity/ degradation on agriculture was solicited. The major response was of low crop yield (98%) and decline in land value (99%) and increased dependence on non- crop earnings (97%). Only 27 percent farmers reported that they were leasing out their land, because no one was ready to lease-in such affected lands.

About half of the communities/ households (49 percent) of the study area were having improved drinking water supply, while 42 percent of them were fetching water from some improved sources like, hand pumps and tubewells installed in fresh water areas and 9 percent were using that saline groundwater. About 97 percent farmers reported that due to use of saline groundwater, chances of more prevalence of water borne diseases were occurred. Similarly in case of animal drinking, wherein about 29 percent farmers were using saline groundwater for animal drinking purpose, they highlighted (95 percent) that animals had to face more diseases in such situation.

Farmers were asked whether they contacted or were contacted by various institutions like line departments (agriculture, irrigating), research institutions, development projects and local khal panchayat regarding their issues. About 50 percent farmers have contacted with departments, while only 11 percent farmers have been contacted by these departments. About 4 percent farmers reported that they had contacted local *khal panchayat*, while 12 percent farmers said local *khal panchayat* has contacted with them for solution of their sufferings.

Logit model analysis have shown that variables of land ownership, value of land rent, high salinity of soils and contacts with departments have made positive and significant relationship, whereas education of farmers and their farming experience has not found significant relationship. The variable of having other sources of income obviously has not shown significant connection because due to their other sources, there was less need to rely on crop income, so not adopting such measures.

5.2 Conclusions

As focus of this research was to assess effects of irrigation induced land degradation (due to saline groundwater) under conjunctive water use environment, on farm productivity and returns, estimating the economic value of such degradation and identifying various factors affecting the adoption of irrigation induced salinity control measures by farmers. Thus, conclusions pertaining to these aspects are inferred as below:

- In degraded areas (having saline/ unfit groundwater) less family members (23 percent) as compared to non-degraded areas (having non-saline/ fit groundwater) were employed in crop production. Overall non-farm (crop) income was 11 percent higher in degraded lands as compared to normal areas, showing more dependence on it.

- Cropping pattern under both categories of farms was more or less same, however cropping intensity was very much low (52 percent) in degraded saline (unfit) groundwater areas as compared to normal areas. This was attributed due to less cropped area.

- Yield was higher under all crops in normal areas. The difference was calculated as 23 percent more in wheat, 25 percent, 34 percent and 31 percent higher in case of Rice, Cotton and Sugarcane crops, respectively sown in normal areas.Net returns per acre under wheat, Rice, Cotton and Sugarcane crops were higher 64 percent, 67 percent, 87 percent and 51 percent in normal areas.

- Economic loss (degraded lands) per acre of sample farmers was Rs.30238 per annum. In overall study areas, these losses were Rs.31.5 million per year and similarly these losses were Rs. 232591 million which amounted to US $ 2326 million per year in Punjab's agrarian (crop production) economy.

- Factors affecting the adoption of such salinity control measures by farmers included status of land ownership, value of land rent, extent of salinity of soils and contacts with line departments have made positive and significant relationship.

5.3 Recommendations

It was evident that there was high threat to these saline lands under prevailing situation. So, there is a dire need to prevent agricultural lands from such sort of irrigation induced (use of saline groundwater) degradation. The followings policy recommendations are hereby suggested.

- Water is generally not perceived as an economic good and therefore revenue recovery from the users is only a small proportion of the cost, resulting in both a drain on government finances as well as deterioration in service. There is a need, both to recover cost and to raise the standard of the service in the surface water sector. Furthermore, the precious water has traditionally been overused and abused. There is a dire need of educating the public of the real value of water to make the users more conscious about it. This would help in reducing demand, would encourage efficiency of usage, and reduce pressure for unnecessary expansion. For this purpose following measures may be adopted:

    - Promote appropriate water pricing system to ensure recovery of at least O&M and capital cost.
    - Develop a groundwater regulatory framework to control and optimize groundwater abstraction.
    - Strengthen monitoring and groundwater modeling to determine sustainable groundwater potential and prepare groundwater budgets for sub-basins and canal commands and to assess the lateral and vertical movement of saline groundwater interface

- Reduce water logging and salinity by improved water management practices

- Special projects on Biosaline agriculture (with some relevant interventions, like gypsum, etc) may be launched in these areas for mitigation and remedial measures.

- There is dire need to assess the irrigation system performance and the optimal ratios of saline and non-saline irrigation water for crop production, so that losses may be minimized.

- Government policy should include plans to divert significant quantities of fresh canal water to areas underlain by saline groundwater on the basis that farmers already have adapted to pumping fresh groundwater.

- There is need to enhance storage capacity of water. This will not only enhance the supply of water but also will minimize the cost of tubewell pumping. This will also lessen the salinity chances of the lands as less quantity of tubewell water would be used to irrigate the lands, which are expected to be saline.

- A paradigm shifts are needed in government policies and the legal and institutional framework of water management is obligatory if water use is to be improved and those effective changes can fruit very big gains in crop output.

- Farmers should be educated and dissemination of technical know-how for adopting coping strategies to the affected farmers through demonstrations on cost sharing basis should be encouraged

5.4 Limitations of the study

The findings of the study be looked- at by considering certain limitations as detailed below:

- The study area is quite representative as far as irrigation induced (use of saline groundwater) land degradation under conjunctive water use, the focus of this study, is a real concern for farmers in the area. However, the choice of the study area brings with it certain limitations with regard to data.

- Irrigation is linked with fluctuated supply of canal water and precipitations occurred in the area which affects the use/ abstraction of groundwater being used as per need. So, such sort of data for 3 to 5 years may also be considered for more appropriate results/ inference.

- It was observed that in saline aquifers zone, groundwater was more saline at the tail end reaches as compared to head end reaches of canal due to more recharge. Thus, extent of such irrigation induced salinity (due to saline groundwater) was varied at these locations. A study of these different locations may help to investigate the extent of losses being occurred and to suggest more précised policy interventions.

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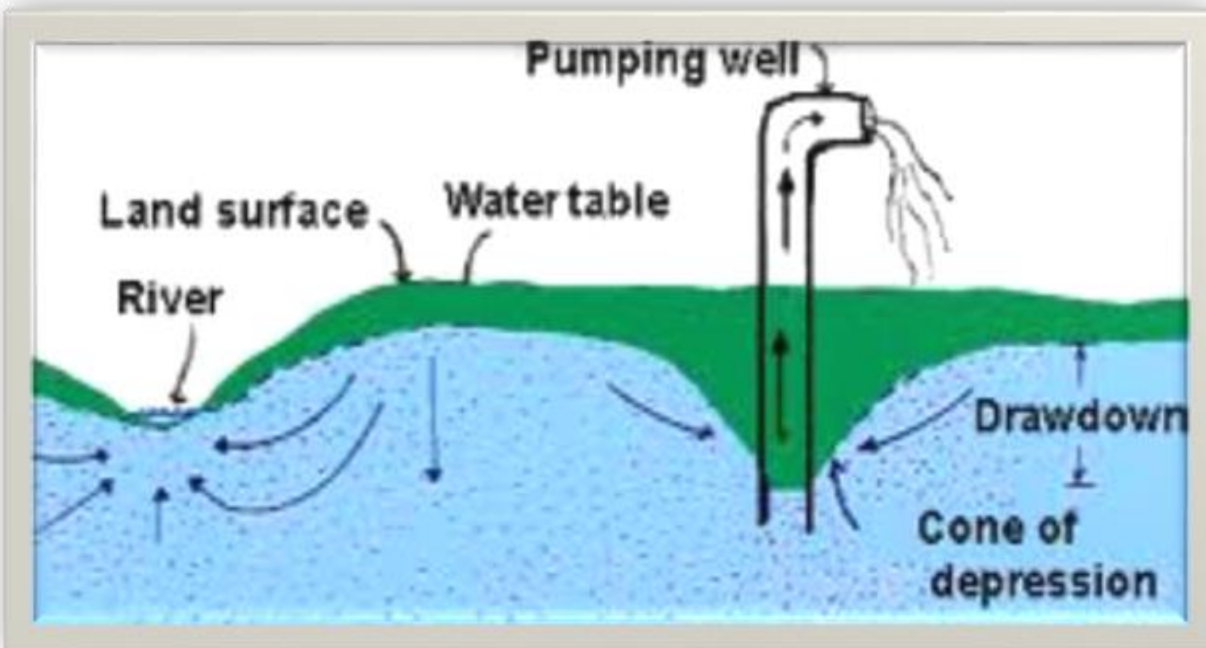
APPENDIX

A Photograph of Tubewell Extracting Water For Irrigation Purpose



A Schematic Diagram Showing Depletion of Groundwater Due To Pumpage

Cotton Sown in Saline Areas

Cotton Sown in Norma Areas

Poor Germination in Saline Areas, Creation of Hard Pan.

Paddy in Normal Areas

Paddy in Normal Areas

Sugarcane in Saline Areas

Sugarcane in Normal Areas

Focused Group Discussion in Village Chaweka

Focused Group Discussion in Village Murrbalochan

Focused Group Discussion in Village Gardiwala

Focused Group Discussion in Village Sansaran

Institute of Agricultural and Resource Economics
University of Agriculture, Faisalabad.

Study for Ph.D Dissertation

ECONOMIC ANALYSIS OF IRRIGATION INDUCED LAND DEGRADATION IN A CONJUNCTIVE WATER USE ENVIRONMENT

Questionnaire for Individual Farmers

(Crop Year : 2012-13)

Case No. ______ G.Water : ______ Location: __________

Cropping System : __________________________ District : __________________________

Tehsil: __________________________ Village: __________________________

Respondent's Name:	Name of Interviewer:
Father's name:	Date of Interview:
Education (Yrs):	Signature:
Age of respondent (Yrs):	Edited by:
Farming Experience (Yrs):	Checked by:
Cell No:	

FARM CHARACTERISTICS

Area owned (Acres)	Area rented-in (Acres)	Area shared-in (Acres)	Area rented-out (Acres)	Area shared-out (Acres)	Total Farm area (Acres)	Culturable waste (Acres)	Total Cultivated Area (Acres)	Land Rent (Rs.)	Value of Land (Rs.)

HOUSEHOLD CHARACTERISTICS

Total Family Members : ______________ Male above 15 Yrs and their detail : ____________________

S.No	Relation with Head	Age (Yrs)	Education (Yrs)	Occupation and Income from Non-Farm Activities			
				Primary (code)	Secondary (Code)	Gross Income Rs/month	Other source of income (per month)
1.							Sale of milk _________________
2.							Remittances
3.							_________________
4.							Pension/other ….
5.							_________________

Occupation Code : 1= Farming, 2=Govt. Service 3= Private Service 4=Entrepreneur/business 5=Inactive , 6= Student, 7= Abroad , 8= Retd. Govt Servant

COST OF PRODUCTION (PER ACRE)

Season	Crop Name/ Code	Area Sown	Land Preparation Cost				Seed		Irrigation				Fertilizers										Plant Protection		Labour used	Harvesting & Threshing cost	Labour (Rs.)	Yield		Value of By-product
			Ploughing & Planking		Other/ *Deep Ploughing				Tubewell	Mix	Total Cost	Canal	Urea (Bags)		DAP (Bags)		SSP (Bags)		Others		FYM									
		Acres	Nos.	Rs/Unit	Nos.	Rs/Unit	Seed Rate (Kg)	Cost/Acre	Nos.	Nos.	Rs.	Nos.	Nos.	Rs/Bag	Nos.	Rs/Bag	Nos.	Rs/Bag	Nos.	Rs/Bag	Trolley Nos	Rs/Unit	Nos.	Total cost (Rs.)	(code)	Rs.		40Kgs	Rs/40 Kgs	Rs.
Kharif 2012																														
Rabi 2012-13																														

Crop Code:Wheat =1, Rice Basmati =2, Rice Coarse =3, Cotton =4, Sugarcane (Plant) =5, Sugarcane(Ratoon) =6, Maize =7, Maize (hybrid) =8, Oil Seed=9, Rabi Fodder=10, Kharif fodder =11, Other =12 (specify …….) Labour Code **:** Family labour =1, Casual Hired Labour= 2, Permanent Hired Labour=3

LIVESTOCK STRENGTH

Animal Type	Total Nos.	Total Value (Rs.)
Buffalo/ Cow		
Goat		
Others ……..		

TUBEWELL AND TRACTOR OWNERSHIP AND COMMERCIAL USE STATUS

Tubewell (owned=1,joint=2)	Income from sale of water (Rs/ year	Tractor (owned=1, joint=2)	Income from Tractor (Rs/ year)

PERCEPTION ABOUT GROUNDWATER QUALITY AND SOIL QUALITY

Period	Groundwater Quality (Y/N)			Soil Quality (% of land)			Area under cultivation (%)
	Fit (Y/N)	Marginally Fit (Y/N)	Unfit (Y/N)	Highly Saline	Moderately Saline	Normal	
Current							
5 Yrs ago							
10 Yrs ago							
20 Yrs ago							

STRATEGIES ADOPTED BY FARMERS TO COMBAT DEGRADATION ISSUES

Strategy	Measure	Adopted (Y/N)	Effective (Y/N)
Irrigation Measures	Cleaning/ lining of minors /water courses to increase surface water		
	Use of chemical ameliorates with saline water		

	HEIS/ RCTs (drip irrigation, sprinkler)		
	Flushing		
	0-Till to conserve "rauni" water		
Cultivation and crop choice	Change in cropping pattern/ crop rotation		
	Increased seed rate		
	Deep Ploughing		
	Ridge/ bed sowing		
	Land leveling		
Fertilizers/organic matte and gypsum use	Increased use of Nitrogenous fertilizers		
	Increased use of organic manure		
	Use of green manuring		
	Use of gypsum		
Other	Specify …………		

REASONS FOR NON-ADOPTION OF COPING STRATEGIES

Reasons	Response (Y/N)
Affected land more to total land	
Groundwater quality is too much poor	
Had other income sources	
Poor economic conditions	
High capital required for reclamation	
Individual actions alone not sufficient	
Lack of incentives and subsidies by Govt.	
Lack of technical know-how	

INSTITUTIONAL CONTACTS BY FARMERS AND BY LINE DEPARTMENTS/ AGENCY w.r.t DEGRADATION ISSUES

Department/ agency	Contacted by Farmers	Contacted by Agency/ Departments

	Response (Y/N)	Effective (Y/N)	Response (Y/N)	Effective (Y/N)
Line department (Agriculture, Irrigation, etc)				
Research Institutions/ Universities				
NGOs working in the relevant field				
Local Khal Panchayat				
Development Project implemented in the area If Yes, name ……………..				
Contacted none				

FARMER'S PERCEPTION ON DEGRADATION ISSUES AND ITS CONSEQUENCES ON AGRICULTURE, HUMAN AND ANIMALS HEALTH

DegradaIndicators	Response (Y/N)
Agriculture and Land	
Development of hard pan	
Salt accumulation and poor germination/ yellowing and crop failure in early stages	
More inputs usage (seed, fertilizer, chemicals, etc)	
More incidence of pests and diseases	
Low crop yield	
Decline in land value	
Shifted resources to other fertile land	
Increased dependence on non-agri earnings	
Family members inclined/ shifting to cities for earnings	
Leasing –out affected land	
Human Health	
Source of drinking water (Code: 1=water supply, 2= Fetching , 3= Groundwater)	
High incidence of human/ water borne diseases if saline groundwater is used	

Animal Health/ Diseases Water used for animal drinking (Code : 1= Canal water pond, 2=Groundwater, 3= water supply)	
Occurrence of animal diseases if groundwater is used for their drinking	

SUGGESTIONS TO OVERCOME THESE ISSUES